No. 23.

(NEW SERIES.)

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

THE ANATOMY AND HISTOLOGY OF TICKS.

BY

CAPTAIN S. R. CHRISTOPHERS, M.B., I.M.S.

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, I
1906.

Price Rs. 3

(*NEW SERIES.*)

No. 23.

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

THE ANATOMY AND HISTOLOGY OF TICKS.

BY

CAPTAIN S. R. CHRISTOPHERS, M.B., I.M.S.

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1906.

(*NEW SERIES.*)

No. 23.

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

THE ANATOMY AND HISTOLOGY OF TICKS.

BY

CAPTAIN S. R. CHRISTOPHERS, M.B., I.M.S.

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1906.

Agents for the Sale of Books published by the Superintendent of Government Printing, India, Calcutta.

IN ENGLAND.

H. S. KING & CO., 65, Cornhill, & 9, Pall Mall, London.
E. A. ARNOLD, 41 & 43, Maddox Street, Bond Street, London, W.
CONSTABLE & CO., 16, James Street, Hay Market, London, W.
P. S. KING & SON, 2 & 4, Great Smith Street, Westminster, London, S.W.
KEGAN PAUL, TRENCH, TRÜBNER & CO., Charing Cross Road, London, W.C.
BERNARD QUARITCH, 15, Piccadilly, London, W.
B. H. BLACKWELL, 50 & 51, Broad Street, Oxford.
DEIGHTON BELL & CO., Cambridge.
GRINDLAY & CO., 54, Parliament Street, London, S.W.

ON THE CONTINENT.

R. FRIEDLÄNDER & SOHN, 11, Carlstrasse, Berlin, N.W.
OTTO HARRASSOWITZ, Leipzig.
KARL W. HIERSEMANN, Leipzig.
ERNEST LEROUX, 28, Rue Bonaparte, Paris.
MARTINUS NIJHOFF, The Hague, Holland.
RUDOLF HAUPT, Halle A. S., Germany.

IN INDIA.

THACKER, SPINK & CO., Calcutta and Simla.
NEWMAN & CO., Calcutta.
S. K. LAHIRI & CO., Calcutta.
R. CAMBRAY & CO., Calcutta.
HIGGINBOTHAM & CO., Madras.
V. KALYANARAMA IYER & CO., Madras.
G. A. NATESAN & CO., Madras.
S. MURTHY & CO., Madras.
THOMPSON & CO., Madras.
TEMPLE & CO., Madras.
THACKER & CO., LD., Bombay.
A. J. COMBRIDGE & CO., Bombay.
D. B. TARAPOREVALA, SONS & CO., Bombay.
RADHABAI ATMARAM SAGOON, Bombay.
N. B. MATHUR, Superintendent, Nazair Kanun Hind Press, Allahabad.
RAI SAHIB M. GULAB SINGH & SONS, Mufid-i-Am Press, Lahore.
Superintendent, American Baptist Mission Press, Rangoon.
SUNDER PANDURANG, Bombay.
A. M. & J. FERGUSON, Ceylon.

List of Numbers of Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India (New Series) published previous to the present issue.

No. 1. Standardisation of Calmette's anti-venomous serum with pure cobra venom: the deterioration of this serum through keeping in India, by *Captain G. Lamb, I.M.S., and Wm. Hanna, Esq., M.B.* Price As. 3 or 4*d.*

No. 2. Malaria in India, by *Captain S. P. James, I.M.S.* Price Re. 1-8 or 2*s.* 3*d.*

No. 3. Some observations on the poison of Russell's Viper (Daboia Russellii), by *Captain G. Lamb, I.M.S., and Wm. Hanna, Esq., M.B.* Price As. 5 or 6*d.*

No. 4. On the action of the venoms of the Cobra and of the Daboia on the red blood corpuscles and on the blood plasma, by *Captain G. Lamb, I.M.S.* Price As. 8 or 9*d.*

No. 5. Specificity of anti-venomous sera, by *Captain G. Lamb, I.M.S.* Price As. 3 or 4*d.*

No. 6. First report on the anti-malarial operations in Mian Mir, 1901-03, by *Captain S. P. James, I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 7. Some observations on the poison of the Banded Krait (Bungarus Fasciatus), by *Captain G. Lamb, I.M.S.* Price As. 8 or 9*d.*

No. 8. A preliminary report on a parasite found in patients suffering from enlargement of the spleen in India, by *Lieutenant S. R. Christophers, I.M.S.* Price Re. 1-8 or 2*s.* 3*d.*

No. 9. Second report of the anti-malarial operations at Mian Mir, 1901-03, by *Lieutenant S. R. Christophers, I.M.S.* Price As. 10 or 1*s.*

No. 10. Specificity of anti-venomous sera (second communication), by *Captain G. Lamb, I.M.S.* Price As. 8 or 9*d.*

No. 11. On a parasite found in persons suffering from enlargement of the spleen in India—Second Report, by *Lieutenant S. R. Christophers, I.M.S.* Price Rs. 2 or 3*s.*

No. 12. On the Morphology, Teratology and Diclinism of the flowers of Cannabis, by *Major D. Prain, I.M.S.* Price As. 14 or 1*s.* 4*d.*

No. 13. Oriental or Delhi Sore, by *Captain S. P. James, I.M.S.* Price As. 10 or 1*s.*

No. 14. On a parasite found in the white corpuscles of the blood of dogs, by *Captain S. P. James, I.M.S.* Price As. 10 or 1*s.*

No. 15. On a parasite found in persons suffering from enlargement of the spleen in India—Third Report, by *Lieutenant S. R. Christophers, I.M.S.* Price As. 10 or 1*s.*

No. 16. The specificity of anti-venomous sera with special reference to a serum prepared with the venom of the Daboia Russellii, by *Captain G. Lamb, I.M.S.* Price As. 6 or 7*d.*

No. 17. Snake-venoms in relation to Hæmolysis, by *Captain G. Lamb, I.M.S.* Price As. 6 or 7*d.*

No. 18. Hæmogregarina Gerbilli, by *Lieutenant S. R. Christophers, M.B., I.M.S.* Price As. 10 or 1*s.*

No. 19. On Kala Azar, Malaria and Malarial Cachexia, by *Captain S. P. James, M.B., I.M.S.* Price Re. 1-4 or 1*s.* 11*d.*

No. 20. Serum-Therapy of Plague in India; reports by Mr. W. M. Haffkine, C.I.E., and various officers of the Plague Research Laboratory, Bombay, by *Lieutenant-Colonel W. B. Bannerman, M.D., B.Sc., F.R.S.E., I.M.S.* Price As. 14 or 1*s.* 4*d.*

No. 21. On the Standardisation of Anti-Typhoid Vaccine, by *Captain George Lamb, M.D., I.M.S. (Director, Pasteur Institute of India)*, and *Captain W. B. C. Forster, M.B., D.P.H., I.M.S.* Price As. 6 or 7*d.*

No. 22. Mediterranean Fever in India: Isolation of the Micrococcus Militensis, *by Captain George, Lamb, M.D., I.M.S., and Assistant Surgeon M. Kesava Pai, M.B., C. M. (Madras).* Price As. 10 or 1*s.*

Published by and on sale at the Office of the Superintendent of Government Printing, India, Calcutta. Copies are also available from all Agents for the sale of Government publications.

THE ANATOMY AND HISTOLOGY OF TICKS.

INTRODUCTION.

WHILE the external characters of ticks have, especially of late, received a good deal of attention from observers, the memoirs of Neumann[23] forming, for example, a complete systematic work on the subject, it is otherwise in the case of the internal structure. This has been scarcely touched upon by most authors, and, so far as I am aware, no full or systematic account of the anatomy of the tick exists. Even isolated observations upon the subject are curiously meagre and very difficult of access.

Yet the existence, almost proved, of a developmental cycle of *Piroplasma* in the tick, and the probability that some spirochætes of the blood of man and animals also undergo developmental changes in the tick, have made it most desirable that we should have at least a general knowledge of the tissues of these blood-suckers.

The following account of the anatomy and histology of *Ornithodoros savignyi* (Audouin) has been written, therefore, with the hope that, by supplying the want already alluded to, it will assist future research upon the development in the tick of the spirochætes of "tick fever" and of other spirilloses. At the same time I have endeavoured to make the work applicable to the investigation of *Piroplasma* by studying a species of *Rhipicephalus* (*R. annulatus*) and one of *Hyalomma* (*H. ægyptium*), examples of the *Rhipicephalinæ* and *Ixodinæ* respectively.

A close study of these two species and a more general investigation of a number of species of different genera, *viz. Hæmaphysalis*, *Ixodes*, and *Aponomma*, has demonstrated in the different scutum-bearing ticks a very close similarity in the structure and arrangement of the organs. Even the differences between the *Ixodidæ* and the *Argasidæ*, are by no means great. I have found it sufficient therefore to describe a single type only, *i.e. Rhipicephalus* to represent the *Ixodidæ*, whilst *Ornithodoros* has been taken as representing the *Argasidæ*. The two types will subserve our present purpose of elucidating the structure of ticks, and one or other type will probably be found applicable, with but few modifications, to any species investigated.

In addition to observations relating to the structure of ticks, I have also added some others upon the life processes, regarding many of which there is

This paper was received on September 12th, 1905.

scope for investigation, and upon the embryology of ticks, a matter of obvious importance, where the production of disease involves hereditary transmission of the virus.

For the opportunity of studying *Ornithodoros* I am entirely indebted to Dr. Oliver of the South Indian Railway, who first drew my attention to the presence of this tick in Southern India, and has kept me supplied with material.

I.

TICKS AS TRANSMITTERS OF DISEASE.

ON account of its great economic importance and also from its intrinsi interest, the reaction of ticks to the piroplasmoses of cattle has been the subject of much work, and has led to the accumulation of a large literature. Smith and Kilborne[1] demonstrated the transmission by ticks of the disease known as Texas Fever of cattle so long ago as 1893. The researches of Koch [2], Theiler [3], and others have since shown that it is possible to distinguish several, apparently distinct, piroplasmoses in cattle, all of which, it would appear, are conveyed by some or other species of tick. Donitz [4], in a résumé of the subj ect gives twelve species of *Rhipicephalus*, which are at present known, or suspected, to be concerned in the spread of these cattle diseases in various parts of the world. It will be sufficient for our present purpose to note that, from the first, it has been recognised, that transmission occurs, not by ticks, which have themselves fed on an infective animal, but by their progeny.

Ticks (*Rhipicephalus bursa*) have been shewn by Motas [5], to convey piroplasmosis in sheep, and Bowhill [6] remarks, that it is more than probable, that piroplasmosis in horses (*P. equi*) is also spread in this way.

Recently Lounsbury [7] has shown that ticks (*Hæmaphysalis leachi*), are intrumental in the transmission of a piroplasmosis in dogs (Malignant Jaundice of the Dog). Nuttall[8] confirms Lounsbury in this respect, and gives some very convincing results, since he succeeded in producing the disease in dogs in England, by means of ticks infected in South Africa. According to Lounsbury, the method of transmission in the case of the dog disease differs from that in Texas fever, in that neither the larvæ, nor the nymphs, from an infected mother are pathogenic. In malignant jaundice of the dog, only the adult ticks derived from an infected mother are capable of giving rise to the disease. Nuttall's results confirm this, inasmuch as his successful cases were obtained with adult ticks, whose mothers alone had fed on infected dogs. There is, therefore, at present a good deal of diversity in the evidence, as to when ticks are infective. The very definite results in the case of the dog disease seems to show clearly, that adults of the second generation may transmit infection, though as larvæ and nymphs they only harbour it. What mechanism is involved in a process apparently so complex cannot at present even be guessed at.

Whilst ticks have been known for some time as carriers of the *Piroplasmata*, it has only recently been ascertained that they are agents in the transmission of certain spirochætæ. The first indication that this is the case was given by the researches of Marchoux and Salimbeni [9], who found a tick, *Argas miniatus*,

concerned in the spread of an epidemic spirillosis among domestic fowls in Brazil. This important discovery had the immediate result of focussing attention upon the subject of tick-borne disease in man, which had, up to this time, been mainly conjectural.

That ticks will at times attack man has been noted by several observers. Anderson [10] and Wilson and Chowning [11] even attribute the transmission of a human piroplasmosis (*P. hominis*) to a species of *Dermacentor*, though Stiles [12] throws grave doubts upon the accuracy of these observations. It would appear that in most cases these ticks are species, whose usual host is some other animal and the only species which at present are actually known to attack man habitually, are certain ticks, which have been made known to us in the first place by travellers. Such ticks have been described as occurring in Persia, and in parts of Africa, but they are also reported from Mexico and elsewhere. Their habits resemble those of the common bed bug, and they appear to be veritable human parasites.

Quite recently our knowledge of these ticks has become more precise, though it is still far from being complete. The differentiation and nomenclature of the species is in some confusion, but they all belong to the *Argasidæ*, and have up to the present been included in two genera, *Argas* and *Ornithodoros*. The species so far known are :—

Argas persicus (Fischer).
Argas tholozani (Lab. et Meg).
Ornithodoros moubata (Murray).
Ornithodoros savignyi (Andouin).
Ornithodoros savignyi var. *cæca* (Neumann).

It is probable that the list will require expansion, especially as recently ticks of this nature have been reported from parts of the world where their presence was not previously known. *Ornithodoros moubata* is an African species, apparently identical with *O. savignyi* var. *cæca* (Neumann), *O. savignyi* (Andouin) also has a wide distribution in Africa, being found in the Cape and in Egypt. A species resembling *O. moubata* is reported from Brazil by Christy [13]. *Argas turicata* (Duges) and *A. megnini* (Duges) are said by Duges to attack man freely in Mexico, and a similar readiness to feed on human blood is noted by Hassal [19] in the case of the American fowl tick *A. miniatus*, and by Gibert [18] for the pigeon tick, *A. reflexus*.

The chief interest in regard to these ticks lies in the fact that their bite is credited with causing, not only acute local symptoms, but also at times severe constitutional disturbance, and even death, an effect which it is difficult to imagine could arise from the normal secretions of the tick. A disease attributed to the bite of the Tete tick (*O. moubata*) is described by both Livingstone and Sir John

Kirk. Daniels[14] has given a description of a case seen by him at Tete and considered the evidence for such a disease convincing. Ross and Milne[15], whilst drawing attention to a so-called "Tick fever" in Uganda, state that, in eight out of eight cases, they have found spirochætes in the blood. Dutton and Todd[16], who had been working independently and in ignorance of the results of the last-mentioned observers, shortly afterwards announced that "tick fever" on the Congo was due to infection with a spirochæte resembling, but not identical with, the *S. obermeieri*, and that it could be transmitted to monkeys by means of the bite of infected ticks. Wellman[20] describing a case of relapsing fever in Angola, considers it probable that "tick fever" is merely infection with *S. obermeieri*, and doubts whether it is conveyed only by ticks. The results of Dutton and Todd, who succeeded in infecting monkeys with young ticks* of the second generation, certainly suggest that the parasite passes through some developmental cycle in the tick, in which case it is probable that the tick acts as the specific agent in its dissemination. At any rate there would appear to be no reason to doubt that such a disease as "tick fever" exists, and it can serve no useful purpose to discuss here the relationship of the spirochæte of tick fever, since at present practically nothing is known concerning human spirillosis.

"Tick fever," as described by the African observers, has a somewhat obscure symptomatology. It has a tendency to relapse, as in the disease due to the *S. obermeieri*. There is extreme constitutional depression, though apparently not, as a rule, high fever. A characteristic symptom is diarrhœa. The spirillum is usually present only in small numbers in the peripheral blood, and is easily overlooked. The disease is therefore not one which is likely to obtrude itself where attention is not specially directed to its diagnosis. So far the disease is known to occur in the Zambesi valley, in Uganda, and at Entebbe on the Congo. It seems not unlikely that it will be found elsewhere.

In India there is no recognised disease of the nature of the "tick fever" of Africa. Captain Browse, I.M.S.[17], has reported spirilla in the blood of man in Northern India, but at present it is impossible to say whether such bodies are *S. obermeieri*, or other spirochætes. As previously remarked, tick fever may, in practice, be readily overlooked, and the disease may still turn out to be of importance in connection with the many obscure fevers, which are so common in Indian hospitals. Even the well-known "Relapsing fever" might well repay more study from the ætiological point of view than it has yet received.

That human ticks are not absent from India was brought to my notice by

---

* NOTE.—In the case of *O. savignyi* (Andouin) the larva, as will be seen later, is inactive and apparently quite incapable of sucking blood. If a similar condition hold good in the case of *O. savignyi* var. *cæca* (Neumann), infection can take place only after the casting of the larval skin and by the nymph.

Dr. Oliver, who has been, so far as I am aware, the first to note their existence. After telling me of a tick known to him as the Tiripati tick, which appeared to be of this nature, he forwarded a number of specimens, which have been identified by Mr. Pocock as *O. savignyi* (Audouin). Afterwards Major Donovan, I.M.S., through one of his students was able to get many specimens from Kalahasti, whilst I have also received several hundreds sent by Dr. Oliver's Assistant, M. P. Veraswamy Naidu, from Tiripati West, Yerfed, Gekakur, and Vendod. I have since received specimens sent by Dr. Chandra Sekar of the Madras Medical College from Tanjore and Conjeeveram. Human ticks are therefore widely distributed in the Madras Presidency and probably elsewhere in India.

Dr. Oliver obtained his specimens from the gravelly floor of the third class passenger sheds, a situation in which many natives are accustomed to spend the night. I have been informed, from another source, that the ticks are also common in Tiripati town, some miles away from the railway station. Dr. Oliver informs me that "ulcers" and severe fever are popularly supposed to result from the bite of the ticks. So far, I have not succeeded in infecting monkeys by means of ticks sent from Tiripati. Most of these were large specimens, and it is possible that younger ticks are necessary for the purpose. Even though the species has not yet been found to transmit the spirochæte of tropical spirillosis, the possible significance of such a blood-sucking parasite of man cannot be overlooked, and it is very desirable that its distribution and comparative prevalence in India should be ascertained.

It is of interest that specimens of the camel tick of Aden sent to me by Captain Patton, I.M.S., are a species of Ornithodoros, probably *O. savignyi*. Captain Patton tells me that these ticks are very common and attack man freely.

II.

The Bionomics of Ticks.

THE life processes of ticks have been observed chiefly in the case of species infesting domestic animals. Hart[30], Hassal[25], Lounsbury[31] and others have also made observations upon the *Argasidæ*. It is evident that considerable scope for investigation, especially in regard to the natural history of the latter family, still exists.

The habits of the *Ixodidæ* and of the *Argasidæ* are by no means similar.

The Ixodidæ.—A number of species of *Rhipicephalus* have been closely observed, as regards their habits, notably *R. Annulatus* by Salmon and Stiles[28] and *R. Decoloratus* by Lounsbury.[29] Theiler [3] and others have described the habits of species of *Amblyomma* and *Hyalomma*. Lounsbury and Nuttall have described very fully the life processes in *Hæmaphysalis leachi* a dog tick. In the main, the habits of the different species are similar, but differences, especially in certain particulars, exist.

The ova of the *Ixodidæ* are laid in masses resembling fish-roe in appearance. Lounsbury gives 2,000 to 4,000 as the number of ova laid by a single gravid female of *H. leachi*. An equally large number is the rule in the family. The eggs are oval in shape and of a light yellow, brown, or red colour. They measure approximately 400 μ by 300 μ in diameter. Hatching takes place, as a rule, only after some considerable time (weeks or months). Many of the ova laid by fully gorged females, which I have at various times removed from naturally infested animals, have failed to hatch out at all. Lounsbury notes a similar heavy mortality in the larvæ. Gravid females of cattle ticks will generally deposit their ova in any situation where they may be confined, but it is very possible that in nature they crawl to some suitable place for the purpose. Lounsbury notes that the dog tick, *H. leachi*, probably, in nature, deposits its ova in cracks, rather than upon the earth. The same habit is very noticeable in the case of the dog tick of Madras, a species of rhipicephalus, which climbs to a height of fifteen feet or more in search for a suitable spot to lay its eggs. Females removed from their host when fully gorged, crawl for two or three days over the bottom of the vessel in which they are confined. Some species readily climb the vertical surface of the glass vessel, but others do not attempt this. Sooner or later the female becomes quiescent and remains at one spot without movement. The plump and distended appearance which the tick exhibits on its first removal from the host gradually becomes less conspicuous, whilst certain very characteristic bright yellow areas appear and increase rapidly in size. These areas are due to the distension of the malpighian

tubules with their products, which at this time accumulate rapidly. At this time also, ticks pass large quantities of a dead white material, which is derived from the malpighian tubules, and cannot be regarded as fæces in the true sense of the term. Coincidently with these changes ova are passed from the genital pore. In ticks at this time, the anterior portion of the body, lying between the first pair of legs, is usually depressed, so as to form a more or less cup-shaped hollow. The lateral edges are accentuated in some instances (*Hyalomma ægyptium*) by a thickening of the chitin. Within the hollow are situated the head and the genital orifice. As the ova are laid, the tick moves slightly backwards, so that the eggs are deposited in a heap in front of it. After the process, which takes several days at least to complete, is over, the tick gradually shrivels up and dies.

On hatching from the ovum, the young larval ticks are minute hexapod creatures. They differ considerably in general appearance from the adult tick, and are without sexual organs. The newly-hatched larvæ attach themselves, as soon as possible, to some vertebrate and suck blood. The larva then gorges itself and after a few days casts its skin. It emerges as an octopod nymph which differs from the mature form mainly in the absence of any sexual opening. The nymph, again becomes engorged, moults, and emerges as the adult tick. The habits at these times vary greatly in the case of different species. *R. annulatus* remains attached to the same host throughout all the changes (Nuttall[5]). According to Theiler[3] the same occurs in the case of *R. decoloratus* (Koch). *Ixodes reduvius*, according to Kossel and Weber[17], leaves its host before becoming adult, as also does *R. evertsi* and *Hyalomma ægyptium* (Theiler). Finally some species leave their host at each change, namely, *H. leachi* (Lounsbury), *R. appendiculatus*, *R. simus* and *Amblyomma hebraeum* (Theiler). Donitz[4] proposes to revive the genus *Boophilus*, founded in 1890 by Curtice, for those Rhipicephali which go through development on the same animal, without detaching themselves at any time, since he finds that such habits are accompanied by certain anatomical characters. Thus, according to this writer, the two first-mentioned species *R. annulatus* and *R. decoloratus* would be contained in the genus *Boophilus*.

After casting the nymphal skin, pairing takes place. The males and females may at this time often be found attached close together, and the male is often covered by the more bulky female. The males, according to Lounsbury, move about and may fertilise several females. Donitz[4] has observed the act of copulation in *Ixodes ricinus*, *R. appendiculatus*, and *R. evertsi*. The proboscis of the male, with the exception of the palps, is inserted into the vulva of the female. The legs of the male, which are used as clasping organs, lie behind the corresponding legs of the female. Donitz was unable to ascertain how the

seminal fluid reached the palps which, judging from their analogy with those of spiders, should be accessory organs of copulation. From anatomical considerations which are discussed later, there can be no doubt that the male passes into the vulva of the female one or more spermatophores, or sacs containing a large number of spermatozoa (see Sect. V, p. 24).

The female, after finally attaching herself, steadily distends with blood. The time during which she remains on the host varies with the species. In the case of some species it may be as short as twenty-four hours. During this time the tick increases enormously in size, the body becoming enlarged out of all proportion to the rostrum and legs. If an attempt be made to remove a tick at this time, considerable force is necessary and the mouth parts are practically torn from their situation in the tissues. When fully gorged the female tick drops to the ground and shortly deposits her ova. After or during this act the female dies. The males do not become gorged in the same manner as the female and are therefore less conspicuous.

The Argasidæ.—The habits of the family have been described in the case of *A. miniatus*, the American fowl tick, *A. reflexus*, the pigeon tick, *O. savignyi* (Audouin), *O. moubata* and a few others. The different species show in the main the same characteristics. My own observations have been made upon *O. savignyi* (Audouin).

The general behaviour of these ticks is quite unlike that of the cattle ticks. As would be gathered from the accounts of travellers, ticks of the genus are mainly nocturnal in their habits, and conceal themselves by day. The specimens from Tiripati buried themselves partly or wholly in the gravel during the day, but issued forth at evening-time, and ran quickly about. At times, especially if one breathes upon or gently disturbs the gravel, the ticks display considerable excitement. If handled they at once sham death. In this condition the legs are closely applied to the body and the tick is readily overlooked among fragments of stick and stone. When running about, the ticks often exhibit a curious habit of raising the first pair of legs, as though receiving in this way information as regards their surroundings. When ticks were placed in glass or porcelain vessels, a rapid tapping sound was sometimes heard. This appeared to be due to a vibration of the hinder portion of the body, which was seen to occur from time to time.

Ornithodorus savignyi is exceptionally hardy and can live many months without food or moisture. Specimens are sent to me in perforated tin cannisters, together with a quantity of the gravel in which they are found. Although the journey by post takes forty-eight hours, the ticks invariably arrive in a living condition. Placed in a dish with a little gravel, many of the ticks have lived without food for over four months.

Even during the day, but especially after dark, the ticks feed readily on monkeys. Major Donovan, I.M.S., informs me that they feed with great readiness on the human subject if merely placed upon the skin. Specimens fed upon monkeys become fully gorged within fifteen minutes. If removed during the process, they offer but little resistance and, indeed, often fall off at a touch. After a full meal most of the sulci, except the more important ones, are obliterated and there is a marked bulging of the ventral surface between the origin of the legs. The head is retracted, and the legs are applied to the body, whilst the animal evinces a tendency, if not disturbed, to lie without movement in the earth upon which it has fallen. A curious feature in regard to the act of feeding was first noticed by Donovan, when feeding some of the ticks in his wards. As the tick distends, fluid is seen to accumulate between the ventral surface and the skin of the host. At first this was thought to be serum which had been voided by the tick. Further investigation makes it probable that, in the main at least, the fluid is not serum, but the secretion of the large coxal glands described later. When handling the larger specimens, one occasionally sees a drop of perfectly clear fluid well up from between the coxæ of the first two pairs of legs. This secretion is very abundant, and several large drops may form in quick succession. Specimens in an unfed condition rarely exhibit this phenomenon, but it is readily observed if the tick is allowed to feed. The fluid is alkaline to litmus, and has a marked effect in preventing the coagulation of blood. After complete engorgement the animal drops to the ground and, being wet with secretion, becomes so covered with adherent particles of soil that it may readily be overlooked. The local effect of the puncture in monkeys is considerable, and, as the tick distends, a zone of ecchymosis is seen extending around the puncture. This area often reaches the size of a shilling or more.

The appearance of extreme rotundity, which is seen immediately after feeding, is lost even in a few days, but the ticks remain distended for several weeks or more. During this time the body gradually regains its flat and sulcate appearance. A short time after feeding the animal casts its skin. After moulting, the ticks are very active and run about as if searching for their prey. The habit of raising the first pair of legs in the air is particularly noticeable at this time. After moulting the ticks feed readily.

Fecundation occurs at various times, and it is not uncommon to find large and fully-grown females, which already contained abundant spermatozoa in the oviducts and spermatheca, in the act of coitus with males. Not only do the males fertilise several females, but females undoubtedly receive sperm sacs from more than one male. During copulation the male, which is usually smaller than the female, hangs ventral surface upwards beneath the female by means of all four legs, which are hooked over the lateral margin of the body of

the latter. The legs of the male are arranged alternately with those of the female, the first pair of the male lying internal to the first pairs of the female. The act is completed by the passage of a large sperm sac into the genital orifice of the female. I have never observed the proboscis of the male within the vulva of the female.

In the main the act of oviposition is carried out similarly in the Argasidæ and Ixodidæ. The female, prior to laying ova, becomes torpid and remains without moving at one spot. Ova are then passed out and remain beneath the body. The whole process takes a week or more. When a female is examined during oviposition, it is seen that the head is forcibly flexed on the body, so that the two pedipalps lie on each side of the genital opening, which at this time gapes widely. Above the head is a curious protuberant mass, not seen in the female at other times. It appears to be the prolapsed duct of the cephalic gland, a structure described later. From the appearance of this body it would seem to serve some very definite purpose during oviposition.

The ova of *O. savignyi* are comparatively few, numbering hundreds in place of thousands as in the cattle ticks. Each ovum is of large size, about one millimetre in diameter. They are globular or very slightly oval, and of a shiny black colour. In captivity they are often scattered over the surface of the gravel, but normally they are laid in a loosely adherent mass, which lies beneath the body of the female. The larvæ hatch very quickly, often in less than a week, and the change to the nymph occurs before another week has elapsed. On hatching, the larvæ are black in colour and globular in shape. The rostrum and the three pairs of short legs are soft and imperfectly developed. The larvæ lie quiescent, often upon their backs, and make no attempt whatever to crawl or to seek food. After three or four days the larval skin is cast, and the octopod nymph escapes. From the first the nymphs are very active, and at once proceed to bury themselves in the sand. They are broad and flat, of a light brown colour, and resemble exactly, in all except size and the absence of a genital opening, the adult tick. They remain alive and active for many weeks without food and exhibit great excitement when the gravel in which they lie is breathed upon or disturbed. They feed readily.

Salmon and Stiles [28] describe the larvæ and nymphs of *Argas miniatus* and *Ornithodoros megnini*. In *A. miniatus* the larva has long and well developed legs with fully formed mouth parts. They are found feeding on the chicken. In *O. megnini* the larva has a very large capitellum and long legs. During the change from the larva to the nymph a quiescent stage (pupa-like stage) supervenes. The nymph differs markedly from the adult in appearance, being covered with spines which are not present in the mature tick.

The larval and nymphal stages of the *Argasidæ* therefore present great

differences in the case of different species and the working out of the details of these stages in *O. moubata* Murray and *O. savignyi* var. *caeca* (Neumann) is required.* Since in *O. savignyi* (Audouin), the larva does not suck blood, and indeed appears quite incapable of doing so, the transmission of disease by this species can take place only after the first moult, and by the agency of the nymph.

In the *Ixodidæ* two changes only of the skin take place, namely, at the larval and nymphal ecdysis. In *Ornithodoros* changes of the skin are many, and occur as the increased growth of the tick demands. In the process of moulting the legs and the rostrum are visible beneath the outer skin, before any rupture of this occurs. Eventually the cuticle is ruptured anteriorly, and separates as a dorsal and ventral sheet.

It has been stated by some observers, that in ticks, a quantity of blood is included in the shell of the ovum to act as reserve material. I have been unable to obtain any evidence that this is so, and, as neither in the ova of *Ornithodoros* nor in those of *Rhipicephalus* is blood to be detected, it is probable that an error has in some way crept in. (Sect. VI, p. 48.)

* NOTE.—Since the above was written, Dutton and Todd have described the larva of *O. moubata* which is inactive.

III.

General Zoological Characters of Ticks.

THE *Arachnoidea*, in which class ticks naturally fall, differ from the *Insecta*, among other important points, in the absence of antennæ, and in the possession of four, instead of three, pairs of walking legs. The *Arachnoidea* include, besides certain marine forms, mainly extinct, a large number of terrestrial species of the following orders: *Scorpiones* (scorpions); *Pedipalpi* (scorpion-spiders, whip scorpions); *Araneæ* (spiders); *Solifugaæ* (Galeodes, *Pseudoscorpiones* (book-scorpions); *Opiliones* (harvest-men); *Acarinæ* (mites and ticks); the *Tardigrada* (water bears); and the *pentastomidæ*.

Typical arachnids possess six pairs of appendages, the first or cheliceres, the second or pedipalpi and the third to the six which form the four pairs of walking legs. The first pair in ticks are converted into piercing mandibles, the second function as labial palps, whilst the four pairs of legs are the third to sixth appendages respectively. In this order also the second pair of appendages (pedipalps) are united at their bases behind the mouth, whilst the third, fourth, fifth and sixth pairs are widely separated.

The most recent classification of the order is that given by Lankester,[2] who recognises seven sub-orders as follows:—

Sub-order *a*. *Notostigmata*.

Possess 10 segments, the anterior four furnished with a single pair of dorsally-placed spiracles.

It contains the form *Opilioacarus*.

Sub-order *b*. *Cryptostigmata*.

The integument is hard. A dorsal and ventral chitinous schlerite is present. The tracheal openings are by stigmata in the articular sockets of the last four appendages.

It contains the family: *Oribatidæ*.

Sub-order *c*. *Metastigmata*.

Integument hard. Tracheæ opening by a single pair of spiracles above and behind the base of the fourth, fifth, or sixth pair of appendages.

It contains the families { *Gamasidæ*, *Argasidæ*, *Ixodidæ*.

Sub-order *a*. *Prostigmata*.

Integument soft. Tracheae, except in the aquatic forms where they are atrophied, open into a pair of stigmata close to or above the base of the chelicera.

The order contains the families { *Trombidiidæ*, *Hydrachnidæ*, *Halacaridæ*, *Bdellidæ*.

Some of the *Trombidiidæ* (harvest-mites), attack man, and others are well known objects, notably the scarlet plush species so commonly seen in the tropics after rain. The *Hydrachnidæ* are water-mites. During their larval stages they may be attached to various aquatic animals. Dye [22] has noted three species attached to adult mosquitoes in Madagascar (*Anopheles*, *Mansonia* and *Culex*). The *Halacaridæ* are marine forms.

Sub-order *e*. *Astigmata*.

Minute species without tracheæ.

The order contains the families { *Tyroglyphidæ*, *cheese-mites*, *etc.* / *Sarcoptidæ*, *Itch-mites*.

Sub-order *f*. *Vermiformia*.

The order contains the family: *Demodicidæ*.

Sub-order *g*. *Tetrapoda*.

The order contains the family: *Eriophidæ*, or water-bears.

The sub-order *Metastigmata* includes nearly all the tracheate forms parasitic on terrestrial vertebrates, and is practically synonymous with the term "tick."

The *Gamasidæ* are small forms found very commonly on beetles, but by no means confined to this order. They have free, filiform palpi and chelate mandibles.

The distinction between the *Ixodidæ* and the *Argasidæ* is based upon the presence, or absence, of a dorsal schlerite or scutum. There are also other and considerable differences between the two families, which are detailed later.

The *Ixodidæ* are sub-divided by Neumann [23] into the *Rhipicephalinæ* and the *Ixodinæ*, the former division containing the genera *Rhipicephalus*, *Hæmaphysalis* and *Dermacentor*, whilst the latter includes the genera *Ixodes*, *Hæmaastor*, *Hyalomma*, *Amblyomma* and *Aponoma*.

The following are the chief characters of the genera mentioned, as given by Salmon and Stiles:

Rhipicephalinæ. Palpi not longer than broad, rostrum short. Anterior portion of body emarginate.

Rhipicephalus.—Eyes present. Base of rostrum hexagonal (dorsally), forming on each side a projecting angle. Palpi short and broad (Fig. 1). Stigmata comma-shaped. Two pairs of clypei in the male. The first coxa with two large teeth (Fig. 5A).

Hæmaphysalis.—Eyes absent. Base of rostrum rectangular, twice as long as broad. Palpi conical. The second segment of the palps has a well

marked lateral conical projection. Stigmata comma-shaped or circular. Anal shields absent in the male. The first coxa not bifid. The fourth coxa in the male has a well-marked spur.

Dermacentor.—Eyes present. Base of rostrum broader than long. Palpi short and thick. Stigmata comma-shaped. Anal shields absent in the males. The first coxa bidentate in the male and female. Scutum ornamented.

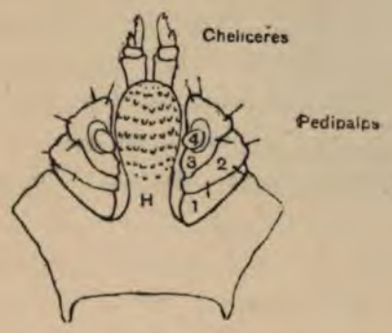

FIG. 1.
Rostrum of a Rhipicephalus.

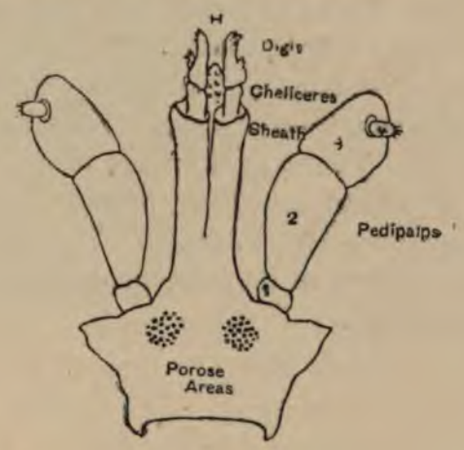

FIG. 2.
Rostrum of Hyalomma.

Ixodinæ. Palpi longer than broad, rostrum long. Anterior portion of body straight or emarginate.

Ixodes.—Eyes absent. Palpi long. Anal groove surrounds anus anteriorly and opens posteriorly. Scutum in the male does not cover the body laterally and posteriorly. Stigmata oval in the male, circular in the female. Male ventrally covered with six shields. Tarsi without terminal spurs. The female has, dorsally, three longitudinal grooves on the abdomen, ventrally, two bell-shaped grooves, the first having its apex at the vulva, the second at the anus.

Hæmalastor.—Eyes absent. Rostrum long. Palpi piriform in the male, claviform in the female. Anal groove as in *Ixodes*. Stigmata circular in both sexes. Legs very long. Dorsal and ventral chitinous thickenings in the male, fine grooves in the female.

Aponomma.—Eyes absent. Anal groove surrounds anus posteriorly and opens anteriorly (Fig. 4). Anal plates absent. Base of rostrum pentagonal. Scutum covers the dorsum entirely; usually marked with green spots; in the female shorter than broad. Stigmata comma-shaped.

Amblyomma.—Eyes present and conspicuous. Anal groove as in *Aponomma*. Anal plates absent. Rostrum long. Scutum often has coloured designs. Stigmata usually triangular. There are nearly always eleven marginal festoons in the male.

Hyalomma.—Eyes present, conspicuous. Rostrum long. Anal groove opens anteriorly. Body elongate oval. Colour deep brown. Male with two pairs of ventral shields, two large triangular perianal and two small external. Scutum covering nearly the whole of the dorsum; crenellated or festooned posteriorly. Stigmata comma-shaped, having a long tail in the male and a short one in the female.

The *Argasidæ* include only two genera: *Argas* and *Ornithodoros*.

Argas.—Eyes absent. The rostrum which is concealed by the cephalothorax is situated at least its own length behind the anterior margin. There is no fold round base of rostrum ventrally (camerostome). The body is oval or orbicular. The integument not mammillated but covered with wrinkles and pits.

Ornithodoros.—Eyes present or absent. Rostrum surrounded ventrally by camerostome (Pl. I., fig. 3.) The tips of the palpi visible from above. The lateral borders of the body generally straight, sometimes concave. Tegument mammillated.

IV.

THE EXTERNAL ANATOMY OF TICKS.

THE exo-skeleton of ticks has been very thoroughly studied by a number of observers, notably by Neumann.[23] It will be necessary only to point out the chief structural features and to indicate the variations which may occur in the different species.

Technique.—The examination of ticks for descriptive purposes cannot, as a rule, be carried out without some special treatment, such as boiling or macerating in caustic potash, which serves the purpose of rendering the parts more transparent. Such treatment is very apt to render the tick distorted and difficult to mount satisfactorily. The following method obviates this tendency and gives excellent results:—The tick to be examined is placed alive upon a glass slip, and covered by a second slip. A rubber band, readily made by cutting a short length from a rubber tube such as is used for bunsen burners, is then slipped over either end of the two slips. The pressure of the glass will cause the tick to assume an extended position, very suitable for examination. A series of specimens may be rapidly put up in this way, and examined at leisure. In this condition, and whilst still alive, a rough diagnostic examination may be made. If it be desired to mount the tick without treatment in alkali, the glass slips should be placed in alcohol until complete hardening of the specimen has taken place. The tick is then removed, placed in fresh absolute alcohol, passed through oil of cloves, and mounted in balsam. The specimen should be lowered into a large drop of balsam which has been previously placed on the slide. Otherwise air bubbles are apt to be troublesome. For the examination of the mouth parts and other details of structure, it is necessary to plunge the tick, still included between the glass slip, into 10 per cent. caustic potash. It may be left to macerate for some hours or, what is usually to be preferred, it is boiled for a time in the solution. In the case of soft-bodied ticks, especially gorged nymphs and larvæ, it is necessary to regulate the pressure, or they may become ruptured, either before or after placing them in the solution. Pressure can be very conveniently regulated by cutting thinner or thicker bands of rubber and a cover glass may be used in place of a slide. The proper degree of exposure must be determined by the transparency of the specimen. It is important to remember that this is increased on removing the specimen from the soda solution to water. When the process of maceration, or boiling, is judged to be complete,

the slides are removed and flooded in water. The rubber bands are then removed, and the slips carefully separated under water by sliding one from the other. The now decolourised tick is quite flat, and resembles a section. The limbs and mouth parts are almost always in perfect position and well displayed. It remains only to soak the skins in water and to pass through alcohol, and oil of cloves, to balsam. If desired, the decolourised tick may be stained in weak fuchsin, a procedure which shows up certain details very clearly, *e.g.*, the teeth of the hypostome. For exact descriptions of such structures as the cheliceres, it may be necessary to dissect up the mouth parts, after boiling in caustic, and to examine them in glycerine.

For *Ornithodoros*, prolonged boiling may be necessary, and for the display of the mouth parts, it is very advisable to remove the dorsal integument preparatory to treating with the caustic.

Very good specimens can often be obtained by utilising the cast skins of young and medium-sized specimens. The only difficulty is that of removing air bubbles. Heating in a large quantity of balsam before mounting will generally get rid of these.

The Ixodidæ.—The *Ixodidæ* when not gorged are flat and more or less disk-shaped in form. Anteriorly is the projecting "rostrum," equally visible from the ventral and dorsal surface. From the lateral and under surface of the body arise the legs, eight in number in the adult, but six only in the larva. Behind the fourth pair of legs are the stigmatic plates. On the ventral surface are the anus and the genital opening, the latter being situated a short distance only behind the rostrum. The integument contains various hard plates (schlerites) one of which, the scutum, covers a portion or the whole of the dorsum, and the arrangement of which differs in different species and in the sexes.

The external organs of generation are scarcely, if at all, distinguishable in the two sexes, but the male and female ticks are, as a rule, readily distinguished by the extent of the scutum, which in the male covers practically the whole dorsum, whilst in the female it covers a small portion, at most one-third. The male also, in most cases, is more ellipsoidal in shape and less regular in outline than the female. The males of certain species also possess certain structures not seen in the female, notably the anal plates, and in some cases, a rudimentary tail. Marginal festoons are more marked in males, and they often possess tarsal spurs which the female is without. (Fig. 6.) The females, on the other hand, may have porose areas, structures not found in the larva, nymph, or male. The females alone become gorged in the manner so characteristic of ticks. Nymphs resemble the adult female more than the male and the scutum covers in them only the anterior third of the dorsum.

The Rostrum or Capitellum.—The rostrum consists of a massive posterior portion (head) prolonged anteriorly into the mouth parts. The rostrum is large and conspicuous in some genera, and may be extremely small, in comparison with the body of the tick, in others. The head may be quadrangular, hexagonal, or approximately globular. It is often prolonged laterally into a sharp process. In some species it is received into a notch in the scutum, in which case the scutum is said to be emarginate, in others the scutum is non-emarginate. On the dorsal surface of the head of the female, in some ticks, are two curious, bilaterally-situated, perforated areas (Porose areas). Fig. 2.

The dorsal surface of the head is continuous with two tubular sheaths, within which the rod-like mandibles (Cheliceres) play. Ventrally the head is continued forwards as a conspicuous dagger-shaped process (Hypostome). On either side of the cheliceres and hypostome are the jointed palps (pedipalpi). The hypostome, cheliceres, and the pedipalpi lie as a rule closely approximated. In the genera in which the palpi are long, they are often found separated from the rest of the mouth parts. Where the palpi are very short and broad, as in *Rhipicephalus*, this separation is rarely seen.

The Hypostome (Fig. 1. H).—The hypostome is continuous with the chitinous exo-skeleton of the head. It is always more or less dagger-shaped though the point may be rounded. The ventral surface carries a number of conspicuous teeth, directed backwards, and usually arranged in several rows. The number of longitudinal rows of teeth is very constant in the same species and is used for identification. Small rudimentary teeth the arrangement of which is irregular are often present about the tip.

The Cheliceres (Figs. 1 and 2).—The cheliceres are strongly chitinised organs, the anterior portions only of which are seen on external examination. The posterior halves, which are swollen, lie in the body cavity, where they receive the attachment of powerful muscles. The anterior portions are rod-like and play each in a sheath, formed by a prolongation forwards of the chitinous covering of the head. The sheaths are lined with a loose membrane, and are covered externally in most cases with fine ridges or teeth. At their termination the cheliceres carry a jointed process (digit). The digit carries several processes (apophyses), which bear large hooked teeth directed backwards. Some authors attach considerable importance to the number and arrangement of these teeth, but Salmon and Stiles state that they are subject to variation in the same species and of doubtful value in identification. The bulbous posterior portion of the cheliceres contains muscles ending in tendons, which are inserted into the digit. The cheliceres may be retracted within, or extruded from, their sheaths by the action of their associated muscles.

The Pedipalpi (Figs. 1 and 2).—These are composed of four joints, of which the details of structure vary much in the different genera. In the *Rhipicephalinæ* the whole pedipalp is very short, thick, and massive. In the *Ixodinæ* it is longer and, as a rule, much simpler, in arrangement. (Figs. 1 and 2.)

In its simplest form, the pedipalp forms a somewhat leaf-shaped organ. The different segments are but little differentiated, and carry only small spines. In the palps of *Rhipicephalus* and *Hæmaphysalis*, the second and third joints are much enlarged, and show considerable elaboration of structure. In *Hæmaphysalis* the second joint carries a sharp process characteristic of the genus. The first joint in the *Rhipicephalinæ* is usually inconspicuous, and of simple form, as, also, is the small fourth joint. The second joint is expanded in a dorso-ventral direction, so that it forms with its fellow a distinct sheath to the mouth parts. It usually carries, on its ventral surface, a row of conspicuous, serrated spines, which meet in the middle line. The third joint is also swollen and often carries dense processes of the chitin. Upon its ventral surface is an area covered with membrane which bears the small papilliform fourth joint. The fourth joint generally carries a terminal bunch of small spines.

The scutum (Fig. 3).—The scutum is a dense chitinous plate, covering in the male the whole, and in the female, a portion, of the dorsum. Its shape varies in different species. It may be emarginate or non-emarginate. It may be furrowed or ornamented with punctures or coloured spots. Perforations (eyes) may be present or absent. Eyes are present in *Rhipicephalus*, *Dermacentor*, and *Hyalomma*, absent in *Hæmaphysalis* *Hæmalastors*, and *Ixodes*.

On the dorsum behind the scutum there are present sometimes two plates resembling the porose areas on the rostrum (Dorso-submedian porose plates).

The anal opening (Fig. 3).—The anus is conspicuous. It is situated about one-third of the body length from the posterior margin. The actual opening is slit-like, guarded by two lateral semi-circular plates of chitin. It is surrounded by various structures utilised in the identification of species, *viz.*, the anal groove, anal plates and ventral plates.

The anal groove (Fig. 4).—A groove (the anal groove) may be present, either anterior to, or posterior to, the anus. In *Ixodes* the groove lies anteriorly, and opens posteriorly. In *Aponomma*, *Hyalomma*, and *Amblyomma*, the position is reversed.

The anal plates or clypei.—These are present in the males of certain species. They are conspicuous plates of chitin, lying on the ventral surface upon either side of the anus. Four plates two on each side, are present

in the male of *Rhipicephalus*. The shape of the plates varies in different species as, for instance, in the case of *R. annulatus* and *R. decoloratus*.

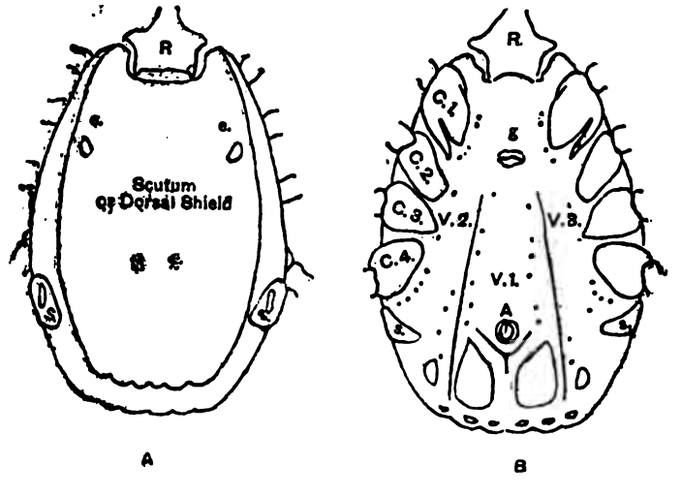

FIG. 3.
Dorsal and ventral views of a male tick (*Hyalomma*).

The ventral shields (Fig. 3).—These are, as a rule, less conspicuous schlerites, which cover the ventral surface in the male. The arrangement of the plates differs in the different species.

Marginal festoons.—Also most marked in the males of certain species,

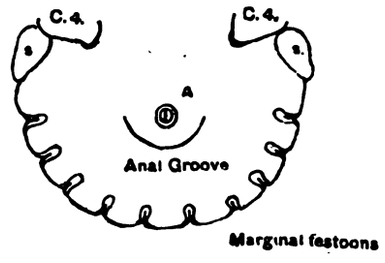

FIG. 4.
Ventral view of *Aponomma*.

notably in *Ambylomma*, where they are eleven in number. The median festoon in some males (*R. decoloratus*, *R. caudatus*), forms a short but distinct tail.

The genital opening.—Close behind the rostrum on the ventral surface is the opening of the genital canal. It is smaller, and much less conspicuous, than in the *Argasidæ*, and in the gorged female is seen only as a minute pore (Pl. VI, fig. 5).

The stigmata.—The stigmal plates, or Peritremes, into which the tracheal system opens, lie behind the origin of the fourth pair of legs. Considerable variation exists in the size and shape of these organs in the different species and genera. They also differ in many cases in the two sexes. They may be circular, or oval, triangular, or comma-shaped as in the males of *Hyalomma*, where they are comma-shaped with a long tail.

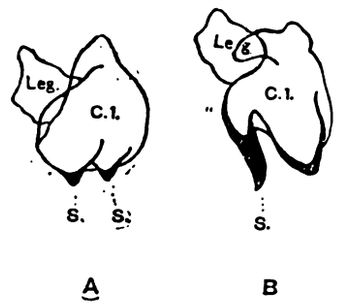

FIG. 5.
Coxae of first pair of legs.
A. *Hhipicephalus.*
B. *Hyalomma.*

The legs.—The legs consist of six podomeres. The basal joints (coxæ) are enlarged and exhibit variations in different species. The first pair of coxæ may show large and conspicuous teeth or may be bidentale (Fig. 5). The fourth coxa in ***Hæmaphysalis*** carries a spine or tubercle. Tubercles may be present on all the coxæ. The podomeres carry certain spines and hairs. The terminal podomere (tarsus) may carry one or more "spurs" (Fig. 6) which are of use in identification of species. The tarsus also carries two large curved claws and a pulvillum.

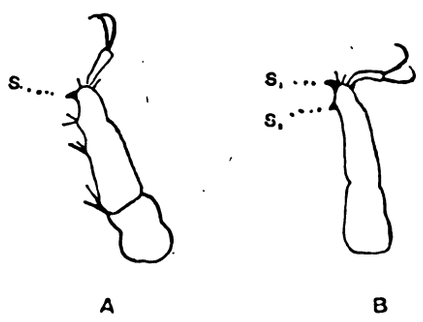

FIG. 6.
A Tarsal joint with a single spur.
B. Tarsal joint with two spurs.

The Argasidæ.—In the *Argasidæ* the head arises from the ventral surface, and the animal is completely devoid of any scutum. The stigmata are situated between the third and fourth legs (fifth and sixth appendages). The limbs, even in fully-grown and gorged animals, are large and strong in proportion to the body.

The pulvillum of the tarsi are absent in the adult. The palpi are free, short, filiform, and consist of 4 segments. The eyes are absent in *Argas* and may be present or absent in *Ornithodoros*. There is a hood-like fold, (the Camerostome) in *Ornithodoros*, lying in front of and around the base of the head. This is not present in *Argas*. The abdomen does not become hypertrophied, as in most of the *Ixodidæ*, out of all proportion to the head and limbs, and growth takes place uniformly, the fully developed animals being identical, in all except size, with the smallest forms. The males are scarcely distinguishable from the females.

A minute description of *O. savignyi* (Audouin) has been given by Neumann. Of this the following is a translation :—

" *Ornithodorus savignyi* (Audouin).

" Body a short oval, rounded at the extremities, sometimes a little pinched in laterally about the region of the origin of the third and fourth legs. Earthy yellow when young, darker yellow or even blackish-brown in the adult state. The terminal points of the legs lighter in colour. The body is covered with granulations, which become larger as the animal increases in size. Hairs are abundant, arising from between the tubercles. On the dorsal surface there is a median prominence, limited behind by a transverse sulcus lying towards the posterior extremity of the body. It is marked in the middle by a depression. Seven similar depressions, one of which is situated at the anterior extremity of the prominence, extend to a certain distance from the anterior edge of the body. Each of these depressions becomes a deeper sulcus behind. The internal ones abut upon the anterior part of the prominence, the two next upon the sides, the two external ones limit laterally the transverse fold, which they join and deepen. Another transverse sulcus is situated just in front of the posterior border of the body. On the ventral surface, a transverse sulcus, concave posteriorly, is situated immediately in front of the anus (pre-anal sulcus), and joins the supra-coxal groove. Behind the pre-anal groove, on each side, are three symmetrical longitudinal depressions, especially well marked in large specimens. The middle grooves are long and incurved at either end. A short reversed γ-shaped depression abuts upon the anus, the limbs lying between the internal and middle sulci. The coxal fold is little marked ; the supra-coxal fold well marked. The folds and grooves are limited behind by the pre-anal sulcus.

" The stigmata are placed behind and above the supra-coxal folds. They are semi-lunar in shape, 600 μ in length. The anal area is broader than long,

450 μ by 400 μ. Four eyes, two on each side, are situated upon the supra-coxal fold, one above the bases of the front pair of legs, the other in the interval between the 2nd and third pairs. They consist of a circular smooth convex prominence 250 μ to 300 μ in diameter.

" The integument is thick, covered with granulations, measuring in the case of large individuals 100 μ to 200 μ. They consist of irregular hemispherical prominences, pointed at their summit, and thickened in the rest of their extent, puckered and crenelated at their base. Between them narrow depressions form a polygonal network. In the large sulci of the dorsal and ventral surfaces the granulations are replaced by oval dimples 50 to 75 μ in diameter, each divided into a large number of small contiguous polygonal areas.

" The rostrum powerful, more or less covered about its base in an infundibuliform camerostome. From the base of the palps to the extremity of the gypostome, about 800 μ in large individuals. Cheliceres 2·4 mm. of which 200 μ is taken up by the digit and 900 by the shank, 1·3 mm. is occupied by the base. The internal apophysis of the digit is in the form of a simple claw, inserted a little behind the middle of the apophysis, external to the basal tooth. The upper tooth is thickened and has a short point. There is no middle apophysis apparent. The sheath is a little thickened in its anterior part, simply striated in the rest of its extent. The hypostome is short, large at the base rounded or pointed at its extremity. The teeth form three longitudinal parallel series on the outer part of the hypostome, of 12 to 13 teeth each, of which the external ones are the strongest. Internally, two or three more or less short series, commencing only in the middle, or posterior third, of the base of the hypostome end behind at the same level. They consist each of 5 to 8 small teeth. There are two spines at the base of the hypostome. The palps measure 1·36 mm. 400, 400, 250, and 310 μ, from first to last joint, respectively. The segments are cylindrical, of rapidly decreasing thickness from the first to the fourth. Upon all sides of each segment there are some thick hairs of unequal size having blunt points. Especially upon the first and not upon the last are some blunt spines. The last segment is rounded at its extremity and is bare without cirri.

" Legs strong, the fourth pair one and one-half times as long as the first. Bases contiguous, decreasing in size from the first to the fourth pair. Striated on the ventral surface. Granular on the dorsal and posterior aspects, with a transversely ribbed pad at the distal extremity. The second segment broader than long in the case of the first two pairs of legs, longer than broad in the others. A little swollen with a distal pad. The third segment very thick at the distal extremity. The fourth segment short in the first three legs, twice as long in the fourth. The fifth segment carries on its dorsal surface, in the first three pairs,

three successive teeth, the two proximal quadrangular, the distal conical. On the fourth pair two conical teeth only. The tarsi carry on their dorsal surface three proximal teeth, a basal one upon the proximal pseudo-segment of the three last pairs, the other close to this. Both are quadrangular. The third is conical and situated near the distal extremity. Thick and rough hairs and small spines are present on all the segments, except on the bases."

In addition to the above minute description, it will be necessary to draw attention only to certain points of special moment. Of the sulci, those of greatest importance, and the only ones which are not obliterated when the animal is fully gorged, are :—

1. *The supra-coxal sulcus.*—This important sulcus, which gives rise to the supra-coxal fold, and extends quite around the anterior portion of the body, is distinguishable even in the larva. The supra-coxal fold itself is a conspicuous structure. It has already been noted as carrying the eyes, which in *O. savigny* var. *caeca* appear to be absent but which are readily made out in the Indian species.

2. *The pre-anal sulcus.*—This is an extremely deep fissure, which forms a landmark in sections.

3. *The sulci about the head.*—The conical head can be retracted to a considerable extent into a fold of the integument (camerostome). At the junction of the two is a deep groove, which is never quite obliterated, even when traction is made upon the rostrum, and becomes much deeper when this organ is retracted. Around the base of the camerostome is a second circular groove, which serves to separate this fold from the coxa of the first pair of legs, the genital orifice, and the supra-coxal fold. The latter part of the groove, that is, the portion lying above the head, is somewhat shallow, and can be smoothed out by forcibly flexing the head upon the body, as occurs in oviposition. When this is done, a broad reversed V-shaped opening is disclosed, into which a stout hair can, without much difficulty, be passed. During oviposition, a protuberant mass, apparently the prolapsed duct of the cephalic gland, projects from this spot.

On the coxæ of the first pair of legs, lying within the groove which separates this from the coxa of the second pair, there is a pore, from which the secretion of the large coxal gland, described later, is at times exuded.

The mouth parts.—The structure and function of the mouth parts have an important bearing upon the question of disease transmission, and it will be most advantageous to discuss them along with the internal anatomy of the tick.

The genital opening.—In both sexes this forms a large and prominent papilla, surrounding a wide transverse fissure. In the male a short horny penis lies within the genital canal, but is not visible externally.

V.

THE INTERNAL STRUCTURE OF TICKS.

Technique.—Ticks are most conveniently examined by preliminary dissection under normal saline, the separate organs being subsequently removed for the purpose of examination in the fresh state, for the preparation of films, or for sectioning. Sections of the whole animal may also be prepared, if certain precautions are observed. The external covering of ticks is extremely resistant to penetration by fluids, and if no opening be made, embedding can with difficulty be carried out. Again, owing to the tension of the body contents, a large incision, prior to hardening, will result in extrusion and considerable displacement of the organs. A very small nick is therefore made in the chitin, at an unimportant part, and the tick placed in alcohol for one hour. If, on further enlarging the incision, the blood is found no longer fluid, slices from 1 to 2 mm. in thickness are made in the required direction. If necessary, the tick may be replaced in alcohol, until the requisite penetration, to allow of this procedure, has taken place. The slices are embedded in paraffin in the usual way, care being taken to use specially dehydrated alcohol, and as short periods in the different fluids as possible. Under this treatment, *Rhipicephalus* cuts very readily. A difficulty occurs in the case of *Ornithodoros*, owing to the very dense cheliceres and apodemes of the head and it is necessary to use very sharp razors. In many cases softening of the tissues in Eau de Javelle may be resorted to.

The sections are fixed upon slides by the hot water method, or by the use of fixative. Obreggios method, though excellent for the study of the relations of the chitinous parts, is not, as a rule, necessary and has several disadvantages.

Except for special reasons, it is undoubtedly preferable to remove the organs separately. They may be fixed in perchloride, or in alcohol. They can be embedded in an extremely short time, owing to their delicacy and ready penetrability.

In the examination for small parasitic forms, sections are by no means so suitable as films or fresh preparations. Films are best made by means of the edge of a microscope slide. If a delicate tissue has been already mounted as a fresh preparation, it can always be converted into a dry film by forcibly sliding off the cover glass.

For the dissection of ticks, a small glass trough, half filled with a mixture of paraffin and lamp-black poured upon lead shavings, is most suitable. The glass troughs used for staining a single slide are convenient, and can be placed, if necessary, on stage of the microscope, or dissecting lens. A lens magnifying fourth or five diameters is most helpful in observing the stages of dissection.

To dissect a tick, it is taken lightly between the finger and thumb of the left hand. With a sharp scissors, very fine tangential slices are snipped from the sides. The dorsal and ventral surfaces, by this manœuvre, should be completely separated except, in the case of the *Ixodidæ*, at the scutum.

At the first snip the distended diverticula will prolapse from the wound, and will be somewhat injured in the subsequent cuts. If ordinary care be taken, this will be found not to interfere at all with the later stages of dissection. Having cut all round the tick, it is gently laved in normal saline to remove free blocd, and is placed in the dissecting dish. By using one pair of forceps to seize the ventral, and another the dorsal flap at their posterior ends, the latter may be readily dragged forward over the head, leaving all the viscera *in situ* attached to the ventral surface. A few fine entomological pins, passed through the edge of the chitin, will retain the tick in position during the subsequent operations. It will be necessary to rock the dish and change the saline from time to time.

The larger specimens of *Ornithodoros* make excellent subjects for dissection. The chief anatomical features can be made out by merely displacing the more massive organs, and by removing with a fine forceps the tissue, chiefly fine tracheal and fat body lobules, which hold these in position.

Over the whole dorsum lies a fine membranous expansion of tracheæ and trabeculæ of the fat body. Lying in this, in the median line, is the delicate tubular heart. Posteriorly, at about the junction of the middle with the posterior third of the body, this is considerably dilated. Stripping off the expansion, the main mass of the viscera, consisting largely of the large dark red blood sacs of the alimentary canal, are exposed. By carefully unravelling these, the arrangement of long diverticula, described later, can be made out. Lying upon the diverticula in the posterior portion of the body is the ovary, studded with developing ova. Upon either side of the ovary, are the coiled oviducts, and in the middle line is the large conspicuous bilobed spermatheca. In almost every region of the body, a portion of the thin coiled malpighian tubules will be found. Behind the spermatheca is an opaque white organ, having very thin saccular walls, and filled with characteristic white secretion from the malpighean tubules. This is the rectum, which in ticks serves as an excretory bladder. By displacing the diverticula from the extreme anterior portion of the body in *Ornithodoros* a bilobed glandular organ, the cephalic gland, is displayed. Further back, the bulbous ends of the cheliceres with radiating muscular fibres are seen. Around them will be noticed the ring-like chitinous fold at the base of the rostrum. By displacing to one side the whole of the anterior and lateral diverticula, a number of further structures are apparent. Passing in from the stigmatic openings is a leash of tracheal branches, of which the large anterior ventral trachea is the most conspicuous.

Lying upon the origin of the first and second legs is the large racimose gland which functions as the salivary gland in ticks. Lifting this gland by its posterior extremity, which lies on the anterior ventral trachea, and tracing it forward, the short salivary duct will be apparent entering the ring-like fold of chitin, already mentioned, immediately beneath the cheliceres. Lying partly under the salivary gland, and partly internal to this structure is a large saccular organ, the coxal gland, conspicuous from the number of tracheæ which supply it.

By careful examination the delicate, colourless œsophagus can be made out entering the lower surface of the large median blood sac of the alimentary canal, whilst lying behind the spermatheca is the fine hair-like termination of the sac in the rectum. To the rectum can be traced the attached end of the two extremely long malpighian tubules. To display the œsophagus in its passage from the pumping organ to the alimentary sac it is necessary to tear away the dense mass of muscle from which it will be seen to emerge. By seizing the muscular mass boldly in the forceps, the unattached entosternum surrounded with muscle will come away, exposing the central ganglion, perforated by the œsophagus. By seizing the bulbous ends of the cheliceres they may be drawn from their sheaths. Lying beneath them is the horizontal, entoschlerite of the head. Beneath this, again, is a dense mass of muscle within which lies the chitinous pumping pharynx.

In the male, in the position of the ovary in the female there is a delicate tube abundantly supplied with tracheæ. On either side this is continuous with a coiled duct much resembling the oviduct in the female. In the middle line, much in the position of the spermatheca in the female, is a curious lobular organ, the white gland.

In *Rhipicephalus* and *Hyalomma* the general relations of the organs are similar to that already described in *Ornithodoros*. The only structures whose nature may not be at first clear in dissections are the long branched cephalic glands, and certain small dermal glands which lie in the fat body.

The following is a detailed description of the organs and tissues of ticks :—

ORNITHODOROS.

The alimentary canal.—Into the floor of the mouth opens a chitinous pharyngeal pump. This leads to a narrow and straight œsophagus, which, after perforating the central ganglion, enters the enormous saccular portion, which with its diverticula forms the great bulk of the body contents. Posteriorly an extremely fine canal, which appears to be a functionless rudiment, joins the central saccular gut with the rectum. Opening into the mouth are the ducts of glands, which function as salivary glands, though they are probably not homologous with the salivary glands of *Scorpio*. Opening into the rectum on

either side is a malpighian tubule. The rectum has some diverticula and terminates in the anus.

The mouth.—The thick and leathery integument of the head passes, almost without a break, into the basal joint of the pedipalps, the hypostome, and a conical prolongation, which ensheaths the cheliceres as far forwards as the level of the proximal end of the second palpal segment (Pl. II fig. 1 *c*). From this point the bare cheliceres lie upon the slightly grooved upper surface of the hypostome. Between the hypostome and the cheliceres, and, further back, between the hypostome and the conical prolongation of the head already mentioned, is a horizontal fissure, the mouth (Pl. II, fig. 9 *m*). Observed from the ventral surface this fissure is not apparent. Dorsally it may be seen opening at the side of the cheliceres, which together are of smaller extent transversely than the hypostome upon which they lie. During life the chelicerest are constantly being protruded and retracted, either simultaneously or individually. Their digits may be projected beyond the end of the hypostome, but are, as a rule, retracted, so as to lie in the hollow of this organ. With the aid of a needle, the cheliceres may readily be separated from one another, and the mouth exposed. The basal joints of the palps, as they join the integument of the head, lie over the edges of the mouth and finally completely close it in at the sides. The mouth, therefore, which anteriorly is a horizontal fissure (Pl. II, fig. 5 *m*), open at the sides, becomes posteriorly a pocket (Pl. II, fig. 6 *m*). This pocket, though of small extent, is of considerable significance. Its roof is formed by the under surface of the dorsal conical projection and consists of unbroken chitin of medium thickness. Above this, lying in loose sheaths in the substance of the projection, are the cheliceres (Pl. II, figs. 5 and 6 *at*.) The cheliceres therefore do not come into connection with this portion of the mouth at all. The floor of the pocket is continuous with the floor of the rest of the mouth, that is with the upper surface of the hypostome. Upon the floor of the pocket is the opening of the pharynx. This is small and is protected by a projecting tongue, which springs from its posterior margin. The actual opening is therefore in the form of a V, the limbs of which are directed backwards (Pl. II, fig. 9 op.). Posteriorly the pocket ends abruptly, and into its two posterior lateral angles open the ducts of the salivary gland of either side. The buccal pocket is bounded laterally by the junction of the integument of the pedipalps with that of the swollen base of the hypostome and the dorsal conical prolongation of the head. The chitin at this place is thickened and not only surrounds the buccal pocket, but gives rise also to important prolongations which pass inwards (Endoschlerites).

Though the tick and the mosquito belong to an entirely different class of anthropod, and the structures are probably in no way homologous, the buccal

cavity of the tick bears a close resemblance to the salivary receptacle described and figured by Dutton[25] in the mosquito. In both the tick and the mosquito the pharynx opens at an angle into the buccal cavity ; in the tick on the ventral, and in the mosquito on the dorsal surface. In both there is a short *cul-de-sac*, lying behind the point of entry of the pharynx, and in both this direct continuation backwards of the mouth receives the salivary ducts or duct.

The Cheliceres.—(Pl. II, fig. 3 *a*.)—The cheliceres, as seen externally, are but a portion of the whole organ. In their entirety they are fang-like structures consisting of a bulbous posterior portion and a narrow anterior extension. The anterior extensions are narrow, strongly chitinised bars which have already been described as lying over the mouth. In their passage through the dorsal conical prolongation of the head they lie surrounded by a loose sheath of a synovial nature. They each contain two tendons passing from the muscles in the bulbous portion to the digit. The posterior halves of the cheliceres are swollen to form large elongated chitinous bulbs which lie closely approximated in the head and have already been mentioned as projecting into the general cavity of the body. The inner ends are devoid of chitin and admit muscles and tracheæ. They also give attachment to numerous muscular bundles, which pass in a radiating manner from an extended origin on the dorsum, to be inserted into the cheliceres. The cavity of the bulbous portion is occupied by numerous muscular bundles, which converge to, and end in, the tendons already mentioned.

The Endoschlerites of the head.—(Pl. II, figs. 3 and 9.)—Where the basal joint of the pedipalps in *Ornithodoras* blends with the base of the hypostome and the dorsal conical prolongation there is a marked thickening of chitin. From this situation an extension passes inwards, blending with the posterior pocket of the mouth, and forming an almost complete transverse bar. From the same situation there extends backwards an extremely strong chitinous bar, which becomes expanded to form, with its fellow of the opposite side, a large horizontal plate. This plate extends almost completely across the cavity of the head, and projects freely into the body cavity. Its upper surface forms, on either side, a broad shallow groove, upon which rest the bulbous portions of the cheliceres. The under surface of the plate gives origin to many muscle bundles, which pass to the pharyngeal pump. By means of the anterior rod-like portions of the endoschlerite, the salivary ducts are supported and carried forwards to the mouth.

The pharynx.—The pharynx forms a typical pumping organ such as occurs in the majority of the blood-sucking *Insecta* (Pl. II, figs. 7 and 9). It consists of chitinous plates arranged so as to give in section a triradiate lumen having a ventral and two lateral limbs. The chief plates are arranged so that one lies beneath, and at a short distance from, the chitinous expansion of the

endoschlerite. The remaining two have a lateral position. Each edge is formed by a double fold, extending the whole length of the structure, and thus allowing a concertina-like expansion to take place, when traction is made by the surrounding muscles. The whole organ is broadly fusiform in shape, narrow at its insertion into the mouth and at its junction with the œsophagus. The anterior portion is bent sharply upwards, and enters the floor of the mouth nearly at right angles. The pharyngeal pump and its muscles occupy the space between the boldly convex lower surface of the head and the endoschleral plate. In dissections it is so surrounded by dense muscle that it is somewhat difficult to display without treatment with caustic. Posteriorly the pharynx ends suddenly in the soft and narrow œsophagus.

The salivary ducts.—(Pl. II, figs. 3 and 9 *s.*)—The short salivary ducts, enter the head on either side by passing close to the ventral surface over the fold of chitin which surrounds the rostrum. They pass forwards, lying at first by the side of, and later just beneath, the edge of the endoschleral plate. Passing to the anterior portion of the endoschlerite they lie in a groove within this. Eventually they pierce the chitin and reach the mouth. The fact that these ducts enter the alimentary tract in front of the pharynx is very much against the view that they represent the ducts of the so-called salivary glands of *Scorpio* or of the spiders. The situation in which they open strongly suggests their homology with the glands serving as poison glands in spiders. These glands open by a duct, which passes through the poison fang, *i.e.*, the pedipalp. Were they to open at the base of this organ, they would exactly represent the condition in the tick. In the tick it seems likely that the dense endoschlerites are in some way connected with the remnants of the conjoined basal segments of the pedipalps, and it is noteworthy that the salivary ducts are intimately connected with these structures.

The œsophagus and proventricular fold.—The œsophagus is a short straight tube, which perforates the central ganglion in its course from the pharynx to the alimentary sac (Pl. III, fig. 1). It is lined with a layer of clear columnar cells with small nuclei. The outlines of these cells have irregularities, which are mutually adapted to one another, and thus give rise to a dove-tailing arrangement. Externally there are muscular fibres. Shortly before entering the alimentary sac, the œsophagus receives a number of muscular bundles which pass in, in a radiating manner, to be inserted into its walls (Pl. III, figs. 3 to 5). At the entrance of the œsophagus into the large blood sac there is a small solid organ. In section this is seen to consist of a thick fold of epithelium, of the same general character as that in the œsophagus, but composed of more columnar and less irregular cells. In the fold there are some thick circular bands of muscular tissue. Outside this are longitudinal fibres passing from the

œsophagus to the gut. The epithelium of the fold passes imperceptibly into that of the œsophagus, but ends abruptly on reaching the wall of the alimentary sac. The organ is very similar to, though still more rudimentary than, the proventricular fold in the mosquito and probably has a similar function. The importance of this fold in the trypanosome infection of *Culex* makes its presence in ticks of moment in connection with infection by spirochætes.

The alimentary sac and its diverticula.—(Pl. III, fig. 7.)—These organs when freshly distended with blood form smooth, dark-red lobulated masses. In *Ornithodoros* the lobulations are very marked, and the diverticula are extremely irregular in outline. In *Hyalomma* they are long and sausage-shaped. In *Rhipicephalus* they usually show constrictions and ballooned portions. As the amount of blood diminishes, the diverticula become almost black in colour, and exhibit innumerable small lobulations.

In the young ungorged tick the diverticula are long and narrow. The walls show active pulsatile movements. This movement, although it can have no effect in drawing blood from the host, undoubtedly must serve to distribute the fluid to the different parts of the sac.

From the entrance of the œsophagus and extending backwards to the neighbourhood of the rectum, there is a large central reservoir which occupies the dorsal prominence already noted in Neumann's description of the species. This structure extends forward a little beyond the entrance of the œsophagus, so that this latter is situated upon the ventral surface of the sac. From the ventral surface posteriorly a conical tag passes downwards behind the spermatheca towards the rectum. This at first contains blood, but as it narrows becomes a clear tube of capillary character. This portion of the canal appears functionally inactive, and it can play no part in the passage of matter from the sac to the rectum. In *Ornithodoros savignyi*, therefore, the alimentary system is practically a closed one.

From the central reservoir a number of blind diverticula are given off. It is stated in some text-books that the arrangement of the diverticula of ticks varies, but, as a matter of fact, the disposition and extent of the diverticula is very constant and according to a very definite plan in all ticks. In *Ornithodoros* the system of diverticula is rather more complex than in the *Ixodidæ*. There is an anterior, lateral, and posterior series. The anterior series is found only in *Ornithodoros*, and is absent in *Rhipicephalus* and *Hyalomma*. It consists of a single medium diverticulum of small size extending forward so as to lie over the cephalic gland (Pl. III, fig. 7 *d. ant.*). The lateral diverticula arise together about the level of the entrance of the œsophagus. They are three in number on either side. The anterior branch is short, the median one is somewhat longer, whilst the posterior lateral diverticulum is of large size and great length. The anterior and middle

branches divide terminally into two or more, usually three, *cul-de-sacs*. The posterior branch divides into two branches, which, after passing down in the neighbourhood of the stigma, curve in on to the ventral surface. The more anterior of the branches ends by the side of the common genital duct. The most posterior surrounds, on either side, the anus and ends a short distance in front of this structure. In *Ornithodoros* irregularities in the arrangement of the diverticula are sometimes seen. Thus, the median lateral diverticulum may be of large size and give rise to the anterior of the two ventral branches (Pl. III, fig. 7). The posterior series consist of four lateral and one median, rather short, diverticula. They all arise close together immediately beyond the atrophied connection with the rectum. The median diverticulum is unrepresented in the *Ixodidæ* which I have dissected.

The various sulci and prominences seen on the surface of *Ornithodoros* have relation to these alimentary diverticula. On the dorsum, the transverse sulcus limits posteriorly the central alimentary sac. Ventrally, the region lying between the coxæ of the four pairs of legs supports upon its inner surface, with which the viscus is in actual contact, the cæcal ends of the posterior lateral diverticula. The lesser prominences correspond in nearly every case with a particular diverticulum and the sulci with the intervals between two diverticula.

The structure of the alimentary sac.—The structure of the sac and of its diverticula is identical. The cavity is lined by a single layer of large cells resting upon a thin basement membrane (Pl. III, fig. 6). Externally there are very large single muscular fibres of a peculiar nature, arranged circularly and longitudinally. These form an open meshwork with square meshes as in the mosquito. The lining epithelial cells are large cells with reticular protoplasm and large vescicular nuclei. Some of them are seen projecting freely into the lumen. Such cells are of especially large size, and have their inner portions much swollen and vacuolated, and they may contain globules of a dense black nature as well as red cells in various stages of intra-cellular digestion. In addition to these large projecting cells there are smaller cells, whose nuclei are situated nearer to the basement membrane. Practically all the cells of the sac contain small densely black granules, evidently derived from the digestion of the blood in the lumen. In undistended diverticula the epithelium may form a more or less continuous lining to the tube, but in the distended tube the cells become very unevenly distributed, being almost absent in some places, whilst in others they form very striking projecting masses.

The process of digestion.—Twenty-four hours after a meal, the greatly distended diverticula are found to contain a soft and imperfect coagulum, from which a considerable amount of fluid blood may drain. On examining the blood at this time the blood corpuscles are seen in an apparently unchanged

condition. Scattered through the fluid, however, are numbers of intensely black granules of a globular shape and measuring from 5μ to ·5μ or less in diameter. In sections these granules are seen collected especially at the periphery of the newly taken in blood, but they are also present in large numbers scattered throughout the mass. The black granules are derived from a previous meal, and there is therefore a considerable degree of mixture between the new blood and the contents of the diverticula prior to the meal.

If the diverticula be examined at some considerable time after digestion has been in progress, some further changes will be observed. On cutting open a diverticulum under normal saline a number of reddish granules, not unlike grains of cayenne pepper, will be seen lying in the still partially fluid blood. These appear quite loose and free from attachments and when washed out fall to the bottom of the dish or among the viscera. On examination they are seen to be globular masses composed of an aggregation of a large number of yellow, red or black granules of large size. Such bodies are especially large, and contain very coarse granules ; in *Rhipicephalus* and *Hyalomma* and in ticks of these genera the contents of the tube which appear at first sight to be soft coagulum may be found to be composed almost entirely of these bodies. It was at first conjectured that the bodies were the inner swollen portions of the cells of the lining epithelium, which had taken up material and become detached. Further investigation, however, has shown that each is an entire cell containing a well-marked nucleus. If films are made of the contents of the sac twenty-four hours after a meal of blood, there will be seen, in addition to the leucocytes of the host, cells derived from the epithelium of the sac. Many of these are evidently the smaller undistended cells, previously noted as lying near to the basement membrane, now detached in the preparation of the specimen. They contain a large circular or oval nucleus, and finely reticular or partially vacuolated protoplasm. Other cells are seen of a similar nature, but larger and with portions of the protoplasm marked by vacuolated and stored with black granules. In addition to such cells, which are those of the epithelium of the sac, there are others which appear to be of a different nature. They are large circular cells with a darkly staining and not very large nucleus. Their substance is markedly vacuolated and crowded with matter which they have evidently engulfed, blood corpuscles, black granules, fragments of chromatin, etc. In sections they are seen, even in specimens made so soon as six hours after the ingestion of blood, apparently lying in isolated positions far removed from the walls of the sac. There appears reason to believe that these cells have a function to perform as wandering digestive cells. Their relation to the epithelium of the sac is not clear. As digestion advances, they become more and more replete with material

and increase in size until they are readily visible to the naked eye as the red granules already noted. In the early stages of digestion, cells packed with chromatin bodies, and resembling superficially macrophages containing the Leishman-Donovan parasite are seen. The nature of these cells which are seen both in *Ornithodoros* and in *Rhipicephalus* is not clear.

Although a prominent part in digestion is taken by the free cells just alluded to, there can be no doubt that the epithelium lining the diverticula also takes an active part in the process. The swollen and vacuolated portion of the large projecting cells is crowded with products of digestion very much as is that of the free cells. The smaller cells lying nearer the basement membrane are also, as a rule, packed with fine black granules, though they rarely contain the large granules seen in the other cells.

The intensely black and opaque globules which have been described, are highly characteristic of digestion in the tick, and undoubtedly represent the ultimate condition to which blood remaining in the gut is reduced by the digestive process. It probably represents only the portion of food not assimilable, for in *Ornithodoros*, ticks of which genus may be kept alive for long periods without food, the diverticula, after some weeks, contain an inky black material consisting entirely of the granules under discussion. In ticks of the *Ixodidæ* family the digestion is not, as a rule, carried to such an extent as to allow of the whole contents being so reduced, and the female usually dies whilst the diverticula still contain much red blood.

As the contents of the diverticula are digested, the muscle fibres, which in the fully distended organ slightly indent the surface, sink more and more into the body of the viscus. The result is that the wall between the fibres becomes ballooned and forms, eventually, flask-like pockets with only a narrow opening connecting with the lumen. This tendency to the formation of pockets is seen in *Rhipicephalus*, but it proceeds to an extraordinary degree in *Ornithodoros*, in which genus the most puzzling appearances may arise both in dissection of the fresh tick, where the whole gut is seen studded with cyst-like bodies, and in sections where without a clue to the condition it is almost impossible to make out the relations of the parts. The epithelium is, as a rule, present in the pockets, though it is generally more noticeable on the ridges formed by the contracted muscular fibres. The remains of ingested blood, in the form of black granules, is present both in the pockets and in the lumen. Ticks (*Ornithodoros*) examined months after a meal still have the diverticula loaded with the black material. As has been previously noted, waste matter is not passed into the rectum and any remnant of food not absorbed must remain in the diverticula until the death of the tick. The method by which absorption takes place has not been ascertained. In no case have I ever detected the black pigment in cells in the tissues or body cavity.

In the case of parasites, these could (by passing through the thin-walled diverticula) at once gain access to the body cavity, and so reach at once many important tissues, including the naked ova, with great ease. It is interesting to note that the system of diverticula is directly derived from the yelk of the ovum. In the nymph the remains of this substance can still be detected (see Section IV), lying in the canal.

The salivary glands and ducts.—(Pl. IV, figs. 1 to 3.)—The salivary fluid in *Ornithodoros* is secreted by two large glands of racimose type, which lie in an oblique position over the bases of the first two pairs of legs on either side (Pl. III, fig. 8). The posterior ends of the glands are situated upon the anterior ventral trachea and the coxal gland. Their anterior ends almost touch the base of the cheliceres.

The gland consists of a number of lobules, formed of closely aggregated globular acini, the ducts from which unite in a tree-like manner and open at intervals around a central duct. This duct arises near the free extremity of the gland and, passing through its whole length, ends as the short salivary duct of one side.

The acini are globular in shape, and consist each of a few large cells, which nearly fill the acinus. Externally there is a limiting membrane. A short spirally striated duct passes from the acinus and joins similar ducts to form the lobular duct (Pl. IV, fig. 2).

Examined in the fresh condition, the cells of the acini are seen to be loaded with large refractile granules. On rupturing an acinus these are set free in the surrounding fluid. In sections of the gland the acini show a somewhat complex structure. One half of the acinus nearly always shows one condition, whilst the opposite half shows another. The individual cells may show one or other of the following conditions, which are probably different stages in the formation of the secretion.

The most conspicuous cells are those in which the protoplasm is crowded with large round or oval granules, which stain deeply with hæmatein, and have a well defined outline and a central darkly stained mass. The granules vary somewhat in size, but average 3 to 5 μ. in diameter. As a rule the cell in which they occur is closely packed with them and the nucleus is not distinguishable (Pl. IV, fig. 3 *b*).

On the opposite side of the acinus a cell is seen containing large granules with indistinct outlines, which stain much less intensely with hæmatein, and possess no central nuclear mass (Pl. IV, fig. 3 *c*).

In many cases areas of vacuolated and coarsely reticular protoplasm are present (Pl. IV, fig. 3 *d*).

The nuclei of these cells are small and appear to have undergone degenerative changes.

The duct is surrounded by small clear cells with small nuclei. Where the duct enters the acinus, there is a large cell with finely reticular protoplasm, which appears never to contain granules, and is probably of a different character from the other cells of the acinus (Pl. IV, fig. 3 *a*). It has a distinct and large vescicular nucleus.

The glands in the larva and nymph.—A good deal of interest attaches to the development of the salivary glands and their condition in the younger stages of ticks. The salivary glands, as first seen in the embryo, consist of a short straight tubule surrounded by large cells. The cells increase in number and form bud-like outgrowths, to each of which a short blind diverticulum from the duct afterwards passes. The buds form a single row of rudimentary acini. Three or four only of these become at all developed in the larva. The immature acini are seen in fresh preparations as clear transparent structures showing a small number of cells arranged around a central lumen. There is often to be made out a delicate inner lining to the cells. The duct appears at first not to communicate with the lumen of the acinus but later lateral offshoots are seen going to each acinus. In section, the cells of the immature acinus have rather darkly staining protoplasm and large conspicuous nuclei. Supporting cells are seen, which appear about to become a capsule.

At the time of casting the larval skin, about fifty acini are present. These form a single row only and each leads by a short duct directly into the central tubule. At this time granules, resembling those seen in the adult, are already present in some of the acini.

The rectum and malpighian tubules.—(Pl. III, fig. 8).—The rectum, which lies immediately behind the spermatheca, or the white gland in the male, is an irregular sac having several capacious but short saccular dilatations. It receives the rudiment of the intestine and the two malpighian tubules. Its walls are extremely thin and consist of a single layer of flattened cells. It contains a white fluid, which is identical with the secretion of the malpighian tubules. The rectum in ticks therefore does not serve as an adjunct to the alimentary canal, but functions as an excretory receptacle. The white matter passed per anum by ticks also cannot, strictly speaking, be regarded as fæces.

The malpighian tubules are important, not only on account of their great length and functional activity in ticks, but also from the frequency with which in other animals such organs are utilised by parasites, and from the fact that Dutton and Todd have traced the spirochætes of "tick fever" to these tubes. They consist of two fine white or transparent tubules of great length, which arise on either side from the rectum, and after a complicated course among the viscera, end blindly in the anterior portion of the body. Near their origin from the rectum they lie upon the ventral surface of the body, and come in relation to

In the case of parasites, these could (by passing through the thin-walled diverticula) at once gain access to the body cavity, and so reach at once many important tissues, including the naked ova, with great ease. It is interesting to note that the system of diverticula is directly derived from the yelk of the ovum. In the nymph the remains of this substance can still be detected (see Section IV), lying in the canal.

The salivary glands and ducts.—(Pl. IV, figs. 1 to 3.)—The salivary fluid in *Ornithodoros* is secreted by two large glands of racimose type, which lie in an oblique position over the bases of the first two pairs of legs on either side (Pl. III, fig. 8). The posterior ends of the glands are situated upon the anterior ventral trachea and the coxal gland. Their anterior ends almost touch the base of the cheliceres.

The gland consists of a number of lobules, formed of closely aggregated globular acini, the ducts from which unite in a tree-like manner and open at intervals around a central duct. This duct arises near the free extremity of the gland and, passing through its whole length, ends as the short salivary duct of one side.

The acini are globular in shape, and consist each of a few large cells, which nearly fill the acinus. Externally there is a limiting membrane. A short spirally striated duct passes from the acinus and joins similar ducts to form the lobular duct (Pl. IV, fig. 2).

Examined in the fresh condition, the cells of the acini are seen to be loaded with large refractile granules. On rupturing an acinus these are set free in the surrounding fluid. In sections of the gland the acini show a somewhat complex structure. One half of the acinus nearly always shows one condition, whilst the opposite half shows another. The individual cells may show one or other of the following conditions, which are probably different stages in the formation of the secretion.

The most conspicuous cells are those in which the protoplasm is crowded with large round or oval granules, which stain deeply with hæmatein, and have a well defined outline and a central darkly stained mass. The granules vary somewhat in size, but average 3 to 5 μ. in diameter. As a rule the cell in which they occur is closely packed with them and the nucleus is not distinguishable (Pl. IV, fig. 3 *b*).

On the opposite side of the acinus a cell is seen containing large granules with indistinct outlines, which stain much less intensely with hæmatein, and possess no central nuclear mass (Pl. IV, fig. 3 *c*).

In many cases areas of vacuolated and coarsely reticular protoplasm are present (Pl. IV, fig. 3 *d*).

The nuclei of these cells are small and appear to have undergone degenerative changes.

of the posterior series of diverticula. It lies directly beneath the expansion of fat tissue and tracheal branches, which cover the viscera dorsally, and in close relation with the dilated posterior portion of the heart, and the malpighian tubules.

The oviducts are long coiled tubes, very delicate where they arise from the ovary, but becoming denser and stouter as they near their termination. A short distance from the ovary there is an enlargement, the significance of which is not clear. On reaching the root of the spermatheca, the oviducts become very thick, and after forming a loop on either side, they enter the substance of this organ, and give to it the characteristic bicornuate appearance.

The spermatheca is a large sac possessing thick walls. If it be opened up, transparent cystic bodies (spermatophores) will be found free in its cavity.

Anteriorly the combined duct of the spermatheca and oviducts passes forwards, lying close to the ventral surface, towards the genital opening. Just before its termination, it becomes thicker and of an opaque white colour. In this portion of its extent it receives some muscular bundles from the endosternum ; upon this portion also lies the central ganglion and a plexus of tracheæ.

The ovary differs in structure entirely from those of insects, and there are no follicular tubes as in this class. The ovary in *Ornithodoros* is essentially a fusiform thin-walled sac, continued at either end into the oviducts. The wall of the sac shows a differentiation into two areas—a dorsal area which gives rise to ova, and a ventral area which has no such function. The dorsal area forms the greater portion of the ovarian sac as usually seen. It is studded over, in more or less regular lines, with ova in different stages of development The ova, except when quite mature, project freely from the outer surface of the ovarian wall. The youngest cells are situated near the edges of the dorsal area, where this passes into the membrane of the ventral surface. The ova, of which there are about ten rows, increase in size as they are situated, further from this situation. The ventral area is composed of a very thin greatly wrinkled membrane. In the undistended state of the ovarian sac, this membrane occupies a small portion only of the circumference. Owing to the extent to which it is folded it is capable of being very greatly stretched. It is therefore more clearly seen when the ovary is distended by the presence of a number of large mature ova in its cavity (Pl. IV, fig. 5 *b*).

The youngest ova are large cells, having extremely large and deeply staining nuclei and a small amount of protoplasm.

More mature ova are large globular or oval cells, having granular or reticular protoplasm, which stains deeply with hæmatein. Afterwards the protoplasm becomes filled with globules which increase in number and size rapidly as the ovum matures. The nucleus is large and vesicular. It contains one or more darkly

staining masses, which show a varying arrangement. The nucleus, as a rule, lies close to the attached end of the cell.

The ova, as they increase in size, project boldly from the surface of the ovary. After reaching a certain size, they become provided with a funicle, composed of altered cells of the ovarian wall. These cells are cubical or columnar, and merge at the base of the funicle with the ordinary, rather flat, cells of the ovarian wall. In the distended ovary, the funnel-shaped funicle is flattened out. The funicular cells then form a flat plate, upon which the now tightly bound down ovum lies. When the ova become mature, they are found lying free and unattached in the lumen of the ovary. Quite how the change is effected, by which the large ova at the end of a funicle come to be within the lumen of the ovary, is not known, as intermediate stages are not often seen. The process would appear to depend on a flattening of the funicle by the pressure and growth of the large ovum, and the eventual forcing open of the ring of cells by the same means.

It is not uncommon to see, in the protoplasm of ova of a certain size, the remains of one of the huge spermatozoa, which characterise *Ornithodoros*. Spermatozoa are present in the ovarian sac, and it appears likely that fertilisation often takes place in this situation.

The fully mature ova, as they are seen after passage into the cavity of the ovary, are globular, of a rich brown colour, and a millimetre in diameter. Their protoplasm is densely packed with droplets of an albuminoid matter and with fine granules. The nucleus is no longer visible. Attached to the ovum at this time there is a curious structure the origin of which is doubtful (Pl. IV, fig. 7).

The oviducts (Pl. IV, fig. 11) are lined with long columnar cells, having clear protoplasm and rather large nuclei, situated near the basal portion of the cell. The outline of these cells is irregular, and they resemble in general appearance the cells lining the œsophagus. External to the epithelial layer are fibres of a muscular nature, and outside these a layer of curious large polygonal cells with large nuclei. The lumen of the oviduct, especially in its lower portions, is distended with masses of gigantic spermatozoa, which often exhibit active and characteristic movements. The spermatheca is similar to the oviducts in structure. It contains a number of spermatophores. The spermatophores are bean-shaped or globular cysts, packed with spermatozoa. They have a hollow stalk, from which the spermatozoa are discharged when pressure is made on the cyst.

The spermatozoa will be described later; but it may be mentioned that in the female they are in a more advanced condition of development than when in the male.

The male organs of reproduction.—(Pl. V, fig. 6.)—Occupying the position

taken by the ovary in the female there is, in the male, a delicate, thin and transparent tubule, ending upon either side in a coiled duct, which much resembles the oviduct in the female. The tubule referred to is from its anatomical relations evidently the testis. It is usually, however, in much of its extent devoid of reproductive tissue. The ducts at either side are, on the other hand, packed with cells in all stages of spermatogenesis. The youngest spermatogenetic tissue is situated in the upper and narrow parts of the lateral ducts, whilst later stages are seen in their lower portions. There is not, however, a regular gradation of development from the upper to the lower parts of the tube, and tissue in an advanced stage may be situated higher than other less mature tissue.

In the other parts of the duct very young spermatogenetic tissue is seen consisting of a stroma of small branched cells enclosing in its meshes from four to six comparatively large cells. These cells have deeply staining protoplasm and large conspicuous nuclei. The stroma cells, which are branched attenuated cells with small nuclei, are attached externally to the wall of the duct. Internally they are arranged so as to leave a central lumen. Between the lumen and the wall, they form loculi, in which the nests of spermatogenetic cells lie.

The cells lying in the loculi, which are at first comparatively small, increase in size until the cells of a single nest occupy the whole lumen of the duct. The stroma cells then disappear, whilst the spermatogenetic cells arrange themselves around the wall of the duct and become attached to it. The cells at this stage are very large and conspicuous, having deeply staining reticular protoplasm and conspicuous nuclei. They soon begin to show further changes. At the outer margin, a curious clear area appears, and rapidly increases in extent. This area appears to be due to a dropsical degeneration of this part of the cell. As the condition progresses, the protoplasm of the cell is pushed inwards, being connected with the outer wall only by strands of its substance. About this time, a cap of very dark staining material appears over the inner surface of the cell, and eventually extends all around it. The nucleus which was at first conspicuous, becomes during these changes difficult to trace. It appears wholly, or in part, to pass to the surface, for a small very dense mass is now seen surrounded by a clear area lying in this position. The appearance of this nuclear mass on the surface determines the formation of one, or possibly more, buds, which, after a complicated development, become spermatozoa. The original cells, whose history we have briefly sketched, would appear to be homologous with the mother cells of the spermatozoa of the earth worm. An interesting fact is the small number, usually only one, of spermatozoa which these cells eventually give rise to.

The Spermatozoa.—(Pl. V.)—These are seen in a fully mature condition only in the female. In the spermatheca and oviducts of the female, *Ornithodoros*

they are seen as relatively immense club-shaped bodies, and are visible as minute rods to the naked eye (Pl. V, fig. 1). Examined fresh they are very transparent. They may be motionless, or may exhibit a steady gliding movement, together with marked vermicular contortions of the anterior portion of their substance. Anteriorly there is a thick bulbous portion, which occupies about one quarter of the total length of the structure. Posteriorly there is a thick tubular tail. Around the extreme anterior tip there is a lip, such as is seen in some filarial embryos. Still further back there is, embedded in the substance of the spermatozoön, a basket-like arrangement, consisting of fine longitudinal lines arranged in the form of a truncated cone (Pl. V, fig. 2). Posteriorly there can usually be seen in the tail two fine filaments. At the extremity there is a tag containing a refractile mass. This tag may be included in the tail or exposed.

The spermatozoa stain with difficulty. Stained with hæmatein they show a large, somewhat lightly staining, mass in the situation of the cone of lines already described. Posteriorly there is darkly staining body, which is that already described in the tag attached to the posterior extremity. The two filaments in the tail also stain (Pl. V, fig. 1).

The spermatozoa in the oviducts are free in the lumen. In the spermatheca they are for the most part included in the cyst-like spermatophores. In both these situations the majority of the spermatozoa show the characters described above.

In the males the spermatozoa are rarely seen in the above condition, but are invaginated upon themselves, so that they are spindle-shaped and about half the length of the extended structure. This curious condition arises from the method in which the spermatozoa develop (Pl. V, fig. 4)

The buds which arise from the mother cells, are anchored by a short stalk at the base of which is the dark granule already mentioned as probably derived wholly or in part, from the nucleus of the mother cell. At the time when the bud has fully formed, this body has passed out of the substance of the mother cell to be in the stalk as noted.

The spermatoblast, which consists of finely granular protoplasm, contains a clear vesicular area of the nature of a nucleus. On the side corresponding to the unattached surface of the spermatoblast, the vesicular area gives rise to a flat prominence. At the opposite pole a conical papilla arises. The spermatoblast and the vesicular area both elongate, whilst the latter shows some fine spiral lines. The originally flat prominence grows out so as to form a long tail. The conical outgrowth of the vesicular area becomes shaped as the head of the adult spermatozoon, and shows a lip as in this structure. Around this end the remains of the protoplasm of the spermatoblast is gathered. The head then invaginates into itself and carries with it the residual protoplasm and

even the nuclear mass in the stalk, which becomes eventually the dark staining body in the tag of the posterior extremity.

Spermatozoa are sometimes seen which have become so invaginated and plicated as to form globular structures. The various steps in the invaginations are rather difficult to follow.

The white glands of the male.—The lower parts of the male ducts are much swollen from the masses of spermatozoa which they contain. They eventually enter a large white lobulated structure, the white gland (Pl. V, fig. 17). The white gland consists of two lateral portions, and a central portion of similar appearance, but of different structure. The lateral portions are merely the continuation of the male ducts, which here become still more dilated. The central portion is glandular in nature. It consists of a double lobulated sac. The walls of the sac, in certain narrow portions of the organ, are composed of columnar cells of extreme length (Pl. V, figs. 18 and 19). In the more swollen portions of the sac, nothing but a mass of albumenoid granules can be made out. It is possible to trace all gradations between the long columnar cells and the final condition in which these have become wholly transformed into the granular substance. The white gland is probably concerned in the elaboration of the spermatophores.

The muscular, tracheal, nervous and circulatory systems.—The muscular system in *Ornithodoros* is well developed. The muscular bundles of the body may be classed as follows :—

(*a*) Muscles of the mouth parts.
(*b*) Muscles of the limbs.
(*c*) Muscular masses of the body.
(*d*) Muscular masses connected with the entostermum.
(*e*) Visceral muscles.

Of the first group we have already noted the muscles lying in the cavity of the cheliceres, which move the digits and apophyses, and those which pass from the dorsal integument to the cheliceres. The muscles acting upon the pumping organ form a dense mass around this structure, and practically fill up the whole of the space of the head beneath the endoschlerite. The muscles of the second group require no special mention in a paper of the present character. Muscle bundles of the third group pass for the most part between the ventral and dorsal surfaces. They lie between the diverticula and support these by forming pockets in which they lie. A conspicuous mass passes up on either side of the spermatheca. Another extensive series lies behind this organ, whilst a third takes its origin from the ventral surface behind the rectum. Fibres from the last two series, as well as passing upwards to the dorsum, pass out to be inserted laterally. Similar dorso-ventral bundles pass between the diverticula in the anterior portion of the body.

The entosternum is densely clothed in muscles which pass in almost every direction to be inserted into the integument and viscera. Specially strong bundles pass out laterally.

The visceral muscle fibres are of a curious type. They show no striations but differ widely from the unstriated muscle of mammals.

The tracheal system is well developed. From the spiracle a leash of tracheæ pass inwards. The tracheæ may be divided into dorsal and ventral branches. The dorsal branches are small. An anterior dorsal branch passes inwards to help in the formation of the dorsal tracheal meshwork, a posterior dorsal branch supplies especially the malpighian tubule and ovary. The ventral branches are much larger, a very large trachea [anterior ventral] passes outside the base of the legs to the anterior portion of the body, where it joins its fellow of the opposite side above the rostrum. At its origin it gives off a large branch which passes in to supply the structures about the entosternum, and to help to form the tracheal ganglion. Just before reaching the salivary gland, it sends a large branch to supply the head and other structures. Besides supplying the salivary gland, it sends branches to the first two pairs of legs. In connection with the branches of this trachea there is a plexus, or tracheal ganglion, beneath the central nerve ganglion and lying over the genital opening.

Another large trachea of the ventral series passes directly inwards to supply the muscles and viscera in the neighbourhood of the spermatheca. A third branch of smaller size supplies the muscles and other structures behind the rectum.

A single nervous ganglion only is visible in dissection. This lies upon the final portion of the common genital canal, and is pierced by the œsophagus. It sends branches outwards to the limbs, and along the œsophagus to the viscera. The structure is similar to that of ganglia in insects, consisting of an inner portion of non-medullated fibres and an outer zone of nerve cells. In comparison with the body of the tick it is of very small size.

The circulatory system is poorly developed. There is a median heart with a dilatation posteriorly. In the young tick this can be seen actively pulsating. Anteriorly the dorsal vessel divides into two branches which dip down in front of the diverticulum to come in relation with the nervous ganglion. Their course is difficult to follow.

The heart in fresh preparations is a transparent structure, having small clusters of granular cells attached to its inner surface. It is abundantly supplied with tracheæ which form long wavy branches. Fine transparent fibres, probably of a muscular nature, are seen in, and attached to, its walls. During the period of oviposition in *Rhipicephalus* large cells, resembling the adventitious cells of the fat body, have been observed in close connection with the heart.

The fat body.—The fat body in insects is recognised to play an important part in nutrition and assimilation. In ticks it consists of numerous trabeculæ, which, bound up with tracheæ, form a loose cellular material. This material lies in among the organs, but is specially abundant about the origin of, and along the course of, the larger tracheal vessels. A somewhat different tissue of a more solid nature occupies certain spaces such as those of the head, pedipalps, and limbs.

The fat body in ticks is a complex tissue and is composed of several forms of cells. It has been by no means well developed in specimens of *Ornithodoros* which I have dissected, and it will therefore be more convenient to describe its structure as displayed in *Rhipicephalus*, where it forms a prominent tissue. So far as could be seen, the tissue in *Ornithodoros* was essentially of a similar nature.

The integument and dermal glands.—The integument consists of a basal cellular portion composed of a single layer of columnar cells and a superficial chitinous layer. In *Ornithodoros* the chitinous layer forms a number of papillomatous-like outgrowths with a hollow core. In *Rhipicephalus* the columnar cells of the dermis are extremely large and conspicuous.

There are a number of glandular structures of dermal origin.

(1) *The coxal gland.*—These are large, flask-shaped organs, very abundantly supplied with tracheæ, which lie upon the second coxal joints, and open by a small pore upon the coxal joint of the first pair of legs. They secrete an abundant clear fluid, which is slightly alkaline and prevents the coagulation of blood. Their presence in *Rhipicephalus* and *Hyalomma* has not been ascertained. They appear similar to the coxal glands of *Scorpio*, as described by Lankester.

(2) *The cephalic gland.*—This remarkable structure which I have so named is of large size, lies above the head and beneath the anterior diverticulum. It consists in *Ornithodoros* of a double plicated sac, with a large cavity opening on the surface by an extremely wide duct, the position of which has been described already. In section it is seen to consist of a single layer of very regular columnar cells, which may contain droplets of fat. The lumen is usually devoid of contents.

RHIPICEPHALUS.

In *Rhipicephalus* and *Hyalomma* the mouth parts are proportionately small in comparison with the alimentary canal and its diverticula. In the main the parts are similar to those of *Ornithodoros* but the relation of the cheliceres to the pumping organ is different (Pl. VI, fig. 10). Posteriorly the canal opens freely into the rectum, but it is doubtful if material ever passes directly from the sac to this organ.

The system of diverticula is in the main similar to that already described in *Ornithodoros*, but in *Rhipicephalus* the structure of the diverticula is simpler and shows more clearly the plan upon which their arrangement is based.

The anterior diverticulum is not present. The lateral series arise from the anterior extremity of the central sac on either side as a single trunk from which arises an anterior middle and posterior branch. The anterior branch passes forwards to the anterior portion of the body. It is often supplemented by one or two small accessory branches (Pl. VI, fig. 4 *a*, *b*). The middle branch occupies most of the lateral regions of the body lying in front of the stigmata. The posterior branch passes down in the neighbourhood of the stigma, and then forwards and inwards to end in front of the genital opening, almost touching the base of the rostrum, and close to, if not in contact with, its fellow of the opposite side.

From the origin of two anterior common trunks the central sac passes backward as a straight cylindrical organ to the level of the anus. At this point two diverticula arise on either side. The inner pair are comparatively short and after passing backwards bend forwards on the ventral surface to reach the neighbourhood of the anus. The outer pair are longer and continue onwards almost as far as the genital opening. From the origin of the posterior series the central sac bends sharply downwards to end in the rectum.

The chief differences between *Ornithodoros* and the present genus lie in a greater complexity of arrangement in the former and in the possession of an anterior and posterior median diverticulum, which are not represented in the latter. The existence of at least an anterior (lateral of the above description) and posterior series of diverticula in ticks appears clear. Whether both are homologous with the so-called "liver" of the *Arachnidæ* I am not at present able to say. As they both lie in the post somatic region it would rather seem that this is the case.

The salivary gland in *Rhipicephalus* occupies a similar position and is essentially of the same nature as in the *Ornithodoros*. The acini are, however, much more loosely held together, and the whole organ is less compact than in this genus (Pl. VI, fig. 7). The structure of the acinus is also much simpler, and shows more clearly the real relation of the acinar cells. Sections show the acini to be lined with a single layer of large cubical cells having clear protoplasm and large vesicular nuclei. About six to eight cells are shewn in cross section (Pl. VI, fig. 8). Some of the cells are larger than others and possess granules.

The malpighian tubules resemble those of *Ornithodoros* and have similar relations to the organs. The importance of the tubules as excretory organs is well shown by the changes which occur at the period of oviposition in *Rhipicephalus*. In a recently removed gorged tick the two long tubules can be seen to have scattered throughout their length, a certain number of crystalline bodies, whilst the rectum is moderately distended. A few days after removal of the fed tick from its host, the malpighian tubules will be found much more opaque

from contained secretion, and they may be dilated here and there into little white sacs. As oviposition advances the tubules and rectum become extremely voluminous, and vie with the blood sacs in size. Eventually the body of the tick consists mainly of these organs. The immense amount of waste matter accumulated by the malpighian tubules in a comparatively short time points to a very rapid and active metabolism during this period.

The generative organs of *Rhipicephalus*, though in general arrangement like those of *Ornithodoros*, differ somewhat in detail. The ovary is much more elongated and lies in the form of a long U in the body cavity (Pl. VI, fig. 11). The oviducts are less conspicuous, except at the period of oviposition than those of *Ornithodoros*. The spermatheca is small and of simple construction (Pl. VI, fig. 13). It forms a simple globular sac opening at the junction of the oviducts into the common genital canal. It contains several spermatophores, which can be seen with their tubes lying directed towards the opening of the sac.

In *Rhipicephalus* there is a tubular gland, opening on either side of the opening of the spermatheca, which appears to be absent in *Ornithodoros*. The structure of this gland calls to mind the mucus glands found in connection with the genital apparatus of many insects.

At the time of oviposition, the oviducts become enormously elongated and form convoluted masses lying upon either side of the anterior portion of the body. Ova are placed at regular and close intervals along their lumen.

The spermatozoa of both *Rhipicephalus* and *Hyalomma* are similar in shape to those of *Ornithodoros*, but they are much smaller being only about one-third the length (Pl. VI, fig. 12). There are also some small differences in the shape and in the movements of the head. Whilst the head of the spermatozoan of *Ornithodoros* exhibits writhing movements those of *Rhipicephalus* show an extraordinary buckling up movement, alternating with a sudden and violent straightening action.

Mention has been made in the case of *Ornithodoros* of a curious gland, the cephalic gland. A similar organ is present in *Rhipicephalus* and is of even larger size. It consists, however, instead of a plicated bag, of a number of long finger-like diverticula which are conspicuous both in careful dissections and in sections (Pl. VI, fig. 5, *e.g.*). In structure the gland is similar to that of the plicated bag of *Ornithodoros*. The presence of so large a gland has led me to examine ticks for the external opening. In *Ornithodoros* this is readily found, in the *Ixodinæ* it is less conspicuous but can in some cases be detected. If the rostrum of *Hyalomma*, which is large, be forcibly bent downwards, so as to lie upon the venter, the floor of the fold between the rostrum and the scutum will be exposed. By means of a lens it is possible to make out in this situation an

inverted V-shaped mark, which appears to be a pore with slightly thickened edges, but I have not succeeded in passing even the finest hair into this opening. The homology and function of this gland, which has not, so far as I am aware, been hitherto described, are obscure. Its large size would lead one to suppose that it served some important functions.

In addition to this organ, there are in ticks a number of small glands undoubtedly of dermal origin lying in the fat tissue. These are small globular bodies, readily seen with a lens. They consist of two gigantic cells lying in a capsule. Fatty degeneration commences at one or more spots and may eventually convert the whole into a mass of minute oil globules (Pl. VI, fig. 2 *c*). These structures, which appear to be oil glands, have not been detected in *Ornithodoros*. In hyalomma they are particularly prominent and one may be led to suppose that they are parasitic in nature.

Opening upon the surface in the neighbourhood of the rostrum there are also some simple acinar glands containing cells of remarkable histological character. Examined in the fresh state they are seen to be composed of enormous cells containing a large vescicular nucleus and a vacuole with a double contour. In section they show a reticular protoplasm and extremely large darkly staining nuclei. The border of the vacuole stains faintly with hæmatein (Pl. VI, fig. 3). These glands lie just beneath the integument of the rostrum and are rather prominent in sections through this organ (Pl. VI, fig. 10 *d*, *g*). They have not been detected in *Ornithodoros*.

The fat body in the gorged female of the *Ixodidæ* is an important tissue. It is specially prominent over the dorsum and in the neighbourhood of the tracheal leashes. The main bulk of the fat body is composed of trabeculæ, formed from polygonal or cubical cells arranged in rows. In certain of these cells the protoplasm is drawn out so as to end in a fine filament, and these act as sustentacular cells by mooring the trabecula to the body wall or other structure. The trabeculæ may be of considerable length, and yet consist of a single row of cells only. In some cases more solid lobular masses are formed, but pads and lobules of the tissue are not characteristic of the tissue in ticks. The cells which compose the trabeculæ may show finely granular protoplasm, or they may be more or less replete with oil globules. As a rule the tissue is not so charged with fat as is the fat body in insects. The sustentacular cells are similar in all respects except in the possession of a filament and in their elongate shape.

Attached to the trabeculæ are cells of an entirely different nature. These are large oval or round cells containing as a rule yellow droplets (Pl. VI, fig. 1 *d*).

In addition to the typical fat body substance which is normally composed of the two varieties of cells, just mentioned, there is in ticks a good deal of cellular

tissue, the exact nature of which it is difficult to determine. Accompanying the branches of the tracheæ are certain free, comparatively small, oval cells. In the same situation are very large cells with deeply stained granular protoplasm. In connection with muscle there are masses of small cells, having processes somewhat like the prickle cells of the human epidermis. In among the trabeculæ of the fat body dermal glands may be encountered.

VI.

The Structure of the Ovum and the Embryology of Ticks.

THE ovum of *Ornithodoros*, when laid, possesses a structureless shell very resistant to the penetration of fluids and even of alcohol. Within the shell is an extremely delicate membrane, which can sometimes be made out in dissections. This membrane encloses a mass of yelk. The yelk is mainly composed of globules of a substance which in sections stains faintly and uniformly with hæmatein, and which appears to be albumenoid in nature. The globules are separated from each other by a trace of more darkly staining granular material.

A few days after oviposition the upper surface of the ovum may shew, under a lens, certain pale translucent spots. These increase in size, whilst others appear, until an opalescent patch, clearly visible to the naked eye, is formed, covering about half the area of one hemisphere. Shortly afterwards the egg shell ruptures, and the globular larva emerges. Examined in detail, the changes at this time are as follows:—

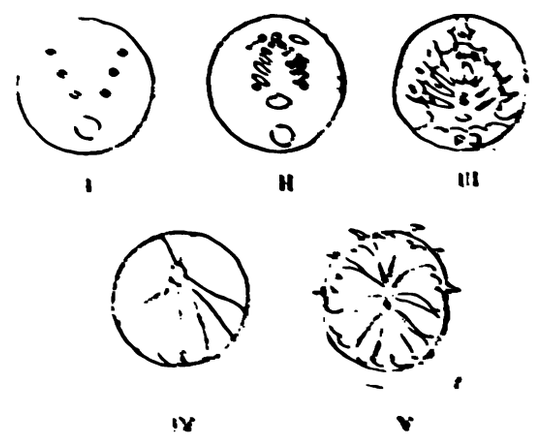

Fig. 1.

I. First appearance of germinal layer.
II. Appearance of rudiments of limbs and tail.
III. Embryo just before hatching. g = ganglion; r = rudiment of rostrum.
IV & V. Formation of alimentary diverticula from yelk. Dorsal view of ovum and newly hatched larva.

The first sign of the formation of the young tick is seen in the presence of three pairs of small translucent spots and one single median spot of larger size.

arranged as in the figure (Fig. 7). The paired spots increase in size, elongate, and approach each other in the middle line. They represent the rudiments of the first three pairs of legs. Other translucent spots make their appearance, a central and two lateral spots showing the future position of the rostrum. A pair of spots anterior to the rudiments of the first legs, and a pair posterior to the third legs, possibly represent the pedipalps and the fourth pair of legs. The last mentioned spots become obscured and are not visible in later stages. A large pale area, the rudiment of the ganglion, appears in the middle line, just behind the rostrum, and between the rudiments of the legs. Some characteristic crystals are already deposited in the region of the rectum, and give rise to a white spot. The large median spot, which forms the point of the V in the arrangement first seen, take up a more and more dorsal position, whilst another median spot rather broad and diffuse appears in front of this and apparently represents a tail, which is not subsequently developed. At the time of hatching the condition of the young tick is

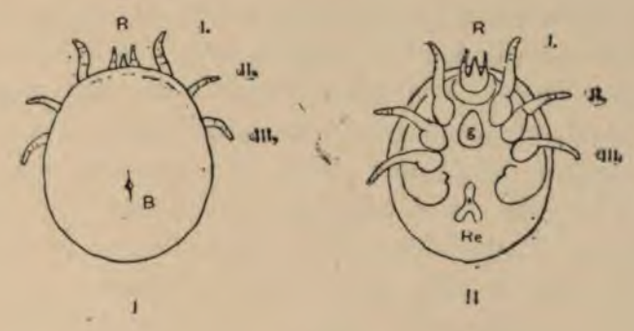

FIG. 8.
I. Dorsal aspect of larva immediately after hatching.
II. Ventral aspect of the same.
R=rostrum; B=the remains of the large polar spot; G=rudiment of ganglion; Re=rectum.

still markedly embryonic. The rudiments of the three legs are distinct, and form conical, rather elongate, projections. The rostrum though imperfectly formed is clearly indicated. The oval rudiment of the ganglion forms a very conspicuous object, as does the collection of excretory crystals in the neighbourhood of the future rectum. Dorsally there is a pale area, the shrunken primitive unpaired spot. From this, as a centre, lines pass out in a radiating manner, which form constrictions of, and divide up, the yelk into lobules. The constrictions already distinctly mark out an anterior, three lateral, and two posterior areas. Ventrally the lobules of the yelk come into distinct relation with the bases of the rudimentary legs. Thus a lobule is present on either side of the rostrum, another lies opposite the base of each of the legs, whilst behind the third leg a pair of lobules on each side curve round towards the midventral line. Posteriorly

four lobules curve round from the dorsal surface and approach the rectum and lateral lobules. Thus the yelk of the ovum represents, in a direct manner, the alimentary sacs of the adult. The remains of the pale spot on the dorsum, from which, as a centre, the constrictions of the yelk take place, represent very exactly the future position of the dilated portion of the heart. The spot is very possibly the blastopore and as such may be connected with the formation of hypoblastic tissue.

In sections, the embryo is seen as a disk of very small cells, which stain intensely with hæmatein. The rudiments of the legs and rostrum are hollow outgrowths of this layer. The rudiment of the ganglion is early seen as a conspicuous mass of cells, and in the larva this organ is relatively of immense size. Muscular fibres, lying especially around the circumference of the yelk, and passing from the dorsal to the ventral surface, are early seen, as also are the crystals of excretory matter. These lie in the yelk in the neighbourhood of the future anus. Short malpighian tubules are seen lying along the ventral surface. At the hatching of the larva the pharynx is seen as a tube, lined by a single row of cubical cells surrounded by radiating cells of a filiform shape, evidently rudimentary muscle fibres. The salivary glands are also present at this time, and consist of some darkly staining cells arranged in groups around a fine central duct. A short straight œsophagus pierces the ganglion, and comes in contact with the yelk. The yelk, as development progresses, becomes more homogeneous in structure. Large cells with an open reticular protoplasm are seen at its periphery, and these multiply and clothe the lobules. In the nymph much yelk still remains in the alimentary canal. The muscles of the limbs are clearly seen in the larva. Around and among them are round or oval cells, containing retractile granules in their protoplasm. These cells appear to migrate into the limbs from the body of the embryo. They undoubtedly represent the first rudiment of the fat body tissue.

The most important fact from a parasitological point of view is that the yelk of the ovum actually becomes the system of alimentary sacs in the adult. Even if the cells, which form the walls of the sacs, are derived from other sources, it is still evident that the alimentary sacs of the nymph of *Ornithodoros* contain the remains of the yelk of the ovum. The pharynx, œsophagus, and salivary duct are formed from an ingrowth of the outer layers of the embryo. The origin of the acinar cells is doubtful, and it is possible that they are mesoblastic in origin. The malpighian tubules seem to be formed from cells in connection with the yelk: it is difficult otherwise to understand how their secretion comes to lie actually in contact with this substance.

In *Rhipicephalus* the amount of yelk in the ovum is relatively small. The early stages of development are similar to those in *Ornithodoros*. The later pro-

cesses have not yet been followed. It is probable that the relation of the yelk to the alimentary sacs of the larva is similar to that described in *Ornithodoros*.

A curious feature of the ova of *Rhipicephalus* is the frequency with which ova contain, or are filled with, what appear to be crystals of fatty acids. I have never found a trace of blood within the shells of eggs deposited by ticks of any of the genera described in this paper, and it is probable that the statements upon this subject which are to be found in several text-books require revision.

PAPERS REFERRED TO IN THE TEXT.

1. Smith and Kilborne. Texas Fever. Washington Bulletin No. 1, 1893.

2. Koch. Reiseberichte über Rinderpest, etc. J. Springer, Berlin.

3. Theiler. East Coast Fever. Journ. Royal Army Medical Corps, December 1904.

4. Donitz. Die Zecken des Rindes als Krankheitsüberträger. Sitzungsberichten des Gesellschaft naturforschender Freunde. Jahrg. 1905, No. 4.

5. Motas. Sur le rôle des tiques dans le developpment de la piroplasmose ovine (Carceag). Comptes rend. soc. de biol., t. LV., pp. 501-504.

6. Bowhill. Equine piroplasmosis or biliary fever. Journal of Hygiene, Vol. IV, 10 January 1905.

7. Lounsbury. Transmission of Malignant Jaundice of the Dog. Report of the Govt. Entomologist (Cape Colony) for 1903. Reprint in Journal of Comp. Pathology and Therapeutics, June 1904, Vol. XVII, part 2.

8. Nuttall. Canine Piroplasmosis. Journal of Hygiene, Vol. IV, No. 2. April 1904.

9. Marchoux and Salimbeni. La spirillosis des poules. Annales de l'Institut Pasteur, t. XVII, p. 569-580.

10. Anderson. Spotted fever of the Rocky Mountains. Treasury Department, Pub. Health and Marine Hospital Service of the U. S. Hygienic Laboratory Bulletin No. 14.

11. Wilson and Chowning. Report on the investigation of so-called "Spotted Fever." 1st Biennial Report of the Montana State Board of Health, 15th March 1901 to 30th November 1902.

12. Stiles. Proceedings of the New York Pathological Society. 30th November 1904.

Abstract in Bull. de l'Inst. Pasteur. Revues et Analyses 30th April 1905.

13. Christy. British Medical Journal, 19th September 1903.

14. Daniels. Reports to the Malaria Committee of the Royal Society 3rd Series.

15. Ross and Milne. Tick Fever. British Medical Journal, 26th November 1904.

16. Dutton and Todd. Mode of Infection in Human Tick Fever. Communicated by R. Ross. British Medical Journal, 4th February 1905, p. 280.

17. Browse. A case showing spirilla in the blood simulating Malaria fever. B. M. J. 11th March 1905.

18. Gibert. L'argas reflexus et son parasitisme chez l'homme. Thèse Bordeaux, 8vo, 1 plate.

19. Hassall. Note on the Chicken Tick, Argas Americanus. Rep. U. S. Depart. of Agric. Animal Industries, XVI, p. 496.

20. Wellman. Case of relapsing fever with remarks on its occurrence in the tropics and its relations to Tick Fever. Jour. of Trop. Medicine, 1 April 1905.

21. Lankester. Quarterly Journal of Microscopical Science, September 1904.

22. Dyé. Les parasites des culicides. Arch. Parasitologie, t. IX, 1905.

23. Neumann. Revision de la famille des Ixodidés. Mémoires Soc. Zool. France, IX, p. 1-44, X, p. 324-420, XII, p. 107-294.

24. Dutton. Report of the Malaria Expedition to Nigeria, 1900. Memoir IV. Thompson Yate's Reports.

25. Hassel. Note on the Chicken Tick (A. Americanus) Sixteenth Annual Report of the Bureau of Animal Industries U. S. Depart. of Agriculture, Washington.

26. Salmon and Stiles. Cattle Ticks of the United States. Seventeenth Annual Report of the Bureau of Animal Industries, 1900. Washington. Government Printing Office.

27. Lounsbury. The Blue Tick (R. decoloratus. Koch). Report of the Government Entomologist for the year 1899. Cape of Good Hope.

28. Hart. The tick of the domestic fowl and fowl fever. Bulletin of Miscellaneous Information. Trinidad III, part 2, April 1899.

29. Lounsbury. Fowl Ticks. Agriculture Journal, Cape Town. Also Pig Lice, *alias* Tampans. Agric. Journal. Cape Town, XIV (4).

Explanation of the lettering on Plate I.

Fig. 1. Lateral view of Ornithodoros savignyi (Audouin) (female).
Fig. 2. Dorsal view of same (female).
Fig. 3. Ventral view of same (female).

Fig 1.

Fig 2.

Fig 3.

Photogravure.

Survey of India Offices, Calcutta. June 1905.

Explanation of the lettering on Plate II.

Ornithodoros.

Fig. 1. Lateral view of rostrum. *a*=mandible; *b*=mandibular sheath; *c*=dorsal aspect of head; *e*=hypostome.

Fig. 2. 1st, 2nd, 3rd, etc. =segments of palp; *e*=hypostome.

Fig. 3. Rostrum and neighbouring parts. Caustic potash preparation. *a*=mandible; *b*=mandibular sheath; *e*=hypostome; *m.*=mouth; *o. s.*=opening of salivary duct into mouth; *ch.*=strong bar of chitin; *t.*=tendons working the mandibular apophyses; *s.*=salivary duct; *chp*=chitinous expansion lying over the pumping-organ; *f.*=fold; *g.*=genital orifice; *Trg.*=tracheal ganglion; *v. t.*=Branch of the anterior ventral trachea; *f. b.*=position of fold at base of head; *t. h.*=tracheæ going to head; *o. p.*=opening of pharynx into mouth; *p*=palps.

Fig. 4. *d.*=digit; *ap.*=apophyses; *i. ap.*=internal apophysis.

Fig. 5. T. S. anterior portion of mouth. *m.*=mouth; *ph.*=commencement of pharynx; *p.*=palp; *at.*=mandibles with tendons of apophyses; *ds.*=dorsal surface.

Fig. 6. T. S. posterior portion of mouth. *aph.*=anterior portion of pharynx; *m.*=mouth; *o. s.*=opening of one salivary duct.

Fig. 7. Transverse section of pharynx (pumping-organ). *l.*=lateral plate; *d.*=dorsal plate.

Fig. 8. *chp.*=chitinous expansion; *s*=salivary duct; *ph.*=pharynx.

Fig. 9. Lateral view of rostrum and neighbouring parts. Semi-diagramatic. *p.*=palp, the basal joint forming part of the lateral border of the mouth; *b*=mandibular sheath; *chb.*=chitinous bar continued back from the base of the palp; *ch.*=chitinous bar; *ms.*=muscle working mandibles; *st.*=stomach; *pr.*=proventriculus; *gl.*=ganglion; *œ.*=œsophagus; *chp.*=chitinous expansion; *s.*=salivary duct; *phr.*=pharynx or pumping-organ; *m.*=mouth; *o. p.*=opening of pharynx into the mouth by a crescentic opening; *o. s.*=opening of the salivary duct into the mouth.

Fig. 1.

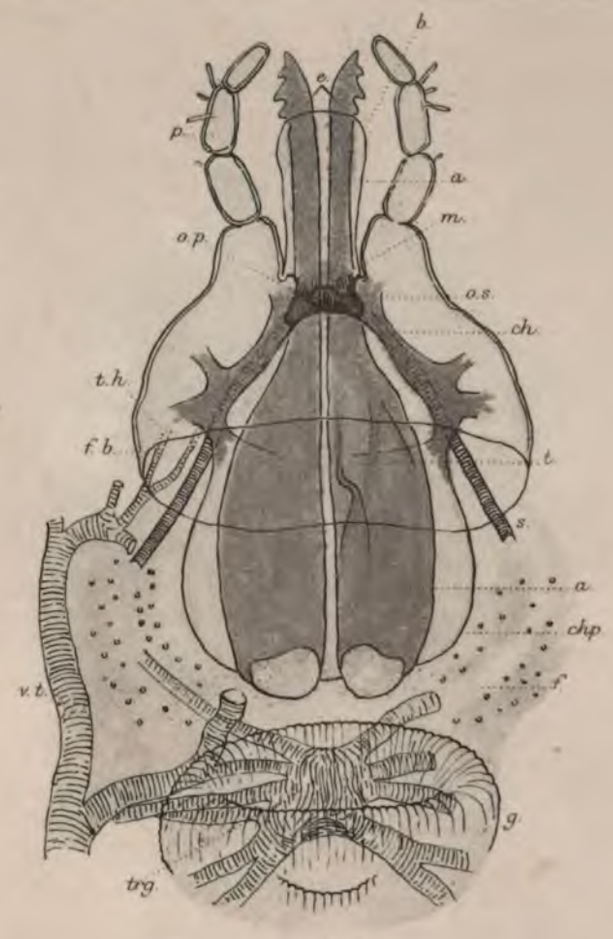

Fig. 3.

Fig. 2.

Fig. 4.

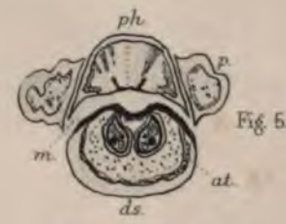

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 9.

Fig. 8.

Photogravure.

Survey of India Offices, Calcutta, June 1905.

Explanation of the lettering on Plate III.

Ornithodoros.

Fig. 1. *ph.*=termination of pharynx; *œ.*=œsophagus; *p.*=proventriculus; *a. s.*=alimentary sac; *g.*=ganglion.

Fig. 2. *a. s.*=alimentary sac; *h g*=rectum; *i.*=rudimentary intestine; *u*=malpighean tubule.

Fig. 3. Section through proventriculus *a.*=œsophagus; *b*=alimentary sac; *p.*=proventricular fold.

Fig. 4. Epithelium of the proventricular fold.

Fig. 5. Epithelium of the œsophagus.

Fig. 6. Epithelium of the alimentary sac. *wc.*=wandering digestive cells containing black granules.

Fig. 7. Diverticula of alimentary canal. *a. s.*=alimentary sac; *d. ant.*=anterior diverticulum; *d. 1.*= ant. latera diverticulum; *d. 2.*=middle latera diverticulum; *d. 3.*=posterior latera diverticulum; *d. 4.* and *d. 5.*=posterior diverticula; *d. post.*=middle posterior diverticulum; *r.*=rectum; *p. o.*=position of the ovary — shown by dotted line; *sp.*=spermatheca; *ov.*=oviduct; *m. t.*= malpighian tubule; *m.*=mandible or cheliceres; *gl.* = cephalic gland.

Fig. 8. Viscera as displayed after removal of the diverticula. *s. gl.*=salivary gland; *o.*=ovary; *ov.*=oviduct; *sp.*=spermatheca; *r.*= rectum; *m. t.*=malpighian tubule; *g*=ganglion.

Fig 1.

Fig 2.

Fig 3.

Fig 4.

Fig 5.

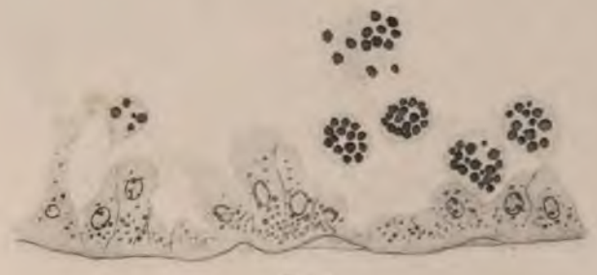

Fig 6.

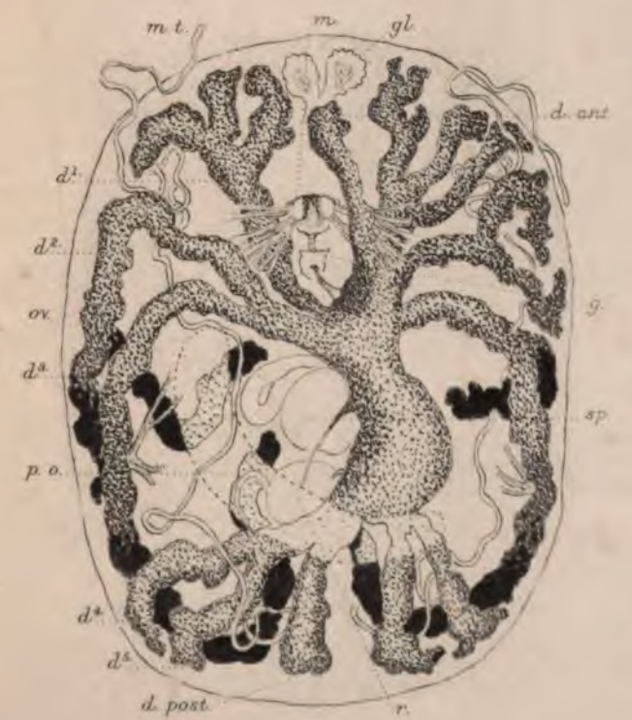

Fig 7.

Fig 8.

Photogravure

Survey of India Offices, Calcutta

Explanation of the lettering on Plate IV.

Ornithodoros.

Fig. 1. Salivary gland of Ornithodoros. Fresh preparation.

Fig. 2. Salivary acini. Fresh preparation. *a*=salivary cell; *b*=globules of secretion.

Fig. 3. Salivary acini. Haematein. *a*=cell at entrance of duct; *b*=deeply staining granules of type; *c*=more lightly staining granules of type 2; *d*=coarsely reticular protoplasm.

Fig. 4. Malpighian tubule. Transverse section. Haematein. *a*=crystals.

Fig. 5. Portion of ovary. Fresh preparation. *a*=oviduct; *b*=ventral portion of the ovarian sac, devoid of ova; *c*=dorsal or ovigerous portion of ovarian sac; *d*=young ovum; *e*=fully mature ovum lying free in the cavity of the ovary.

Fig. 6. Section of a portion of ovary. *a*=ovum; *b*=ovarian wall; *c*=funicle.

Fig. 7. Mature ovum from cavity of ovary.

Fig. 8. Ovum and funicle. Haematein.

Fig. 9. Very young ovum on ovarian wall. Haematein.

Fig. 10. Maturing ovum with flattened funicle. *a*=nucleus of ovum; *b*=the remains of a spermatozoan; *c.*=cells of the funicle; *d*=ovarian wall.

Fig. 11. Section of portion of wall of oviduct. *a*=internal layer of columnar cells; *b*=muscular tissue; *c*=layer of polygonal cells.

Fig. 12. Spores of a "nosema" from ovum.

Fig.1.

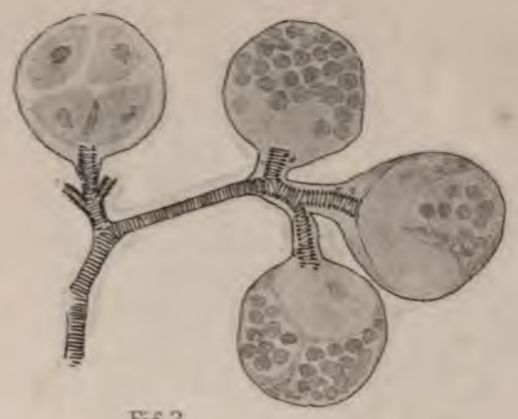

Fig.2.

Fig.3.

Fig.6.

Fig.5.

Fig.7.

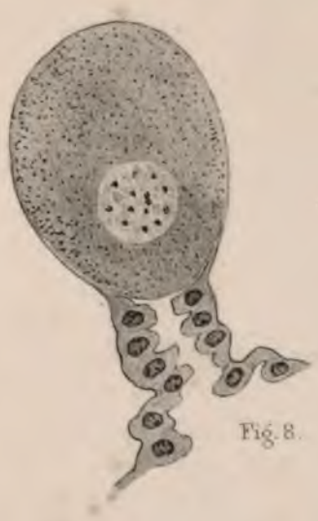

Fig.8.

Fig.9.

Fig.10.

Fig.4.

Fig.12.

Fig.11.

Photogravure.

Survey of India Offices, Calcutta, June 1935.

Explanation of the lettering on Plate V.

Ornithodoros.

Fig. 1. Spermatozoan of ornithodoros. Haematein.
Fig. 2. Head of spermatozoan. Fresh preparation.
Fig. 3. Head of spermatozoan exhibiting characteristic movements.
Fig. 4. Spermatozoan as seen in male.
Fig. 5. Spermatophore from spermatheca of female. *a*=spermatozoa; *b*=cyst-like capsule.
Fig. 6. Male reproductive organs.
Fig. 7. Section of undeveloped testis. Haematein. *a*=nests of mother cells of spermatozoa; *b*=stroma cells; *c*=lumen.
Fig. 8. Section of developing spermatozoa. Haematein. *a*=Fully-grown mother cell of spermatozoan lying with the remaining cells of the nest in the enlarged loculus; *b*=mother cell immediately prior to budding of the spermatoblasts; *c*=passage of altered nuclear matter to surface of cell; *d*=basal portion of swollen mother cell; *e*=developing spermatoblast; *f*=nuclear body derived from mother cell.
Figs. 9—14. Development of spermatozoan from spermatoblast. Fresh preparations.
Figs. 15 and *16.* „ „ „ „ „ Haematein.
Fig. 17. Section of "white gland." Haematein. *a*=portion with unaltered epithelium; *b*=portion exhibiting altered epithelium; *c*=terminal portion of vas deferens.
Fig. 18. Epithelium from the portion "*a*" in figure 17.
Fig. 19. Epithelium from the portion "*b*" in figure 17.
Fig. 20. Spermatophore containing the bodies shown in figure 21.
Fig. 21. Curious bodies sometimes seen in spermatophores.

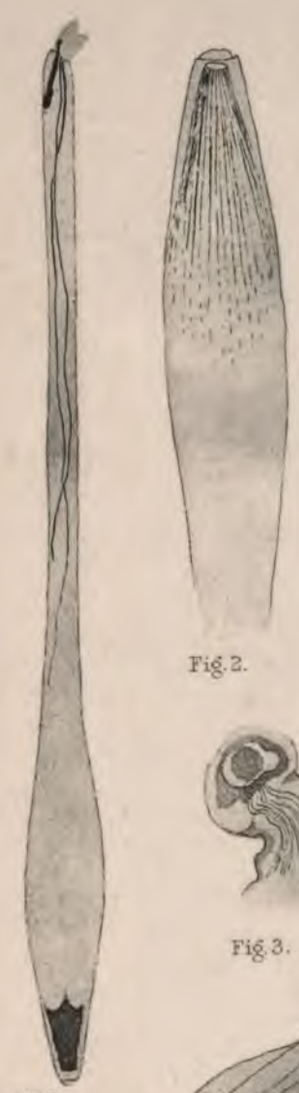

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

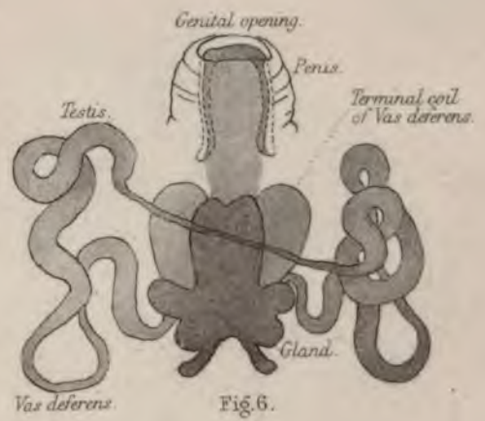

Fig. 6.

Fig. 5.

Fig. 7.

Fig. 8.

Fig. 21.

Fig. 20.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 15.

Fig. 13.

Fig. 16.

Fig. 14.

Fig. 17.

Fig. 18.

Fig. 19.

Photogravure.

Survey of India Offices, Calcutta, June 1908.

Explanation of the lettering on Plate VI.

Rhipicephalus and Hyalomma.

Fig. 1. Fat body. Fresh preparation. *a*=sustentacular cell; *b*=fat body cell with little or no fat in its substance; *c*=fat body cell containing fat droplets; *d*=cell of unknown nature, the adventitious cells of the fat body; *e*=large granular cells.

Fig. 2. Section through cuticle and interstitial tissue. *a*=oval cells lying near trachea; *b*=large darkly staining cells; *c*=dermal gland (Hyalomma).

Fig. 3. Dermal gland occurring about the rostrum. (Rhipicephalus) *v.*=vacuole with double outline.

Fig. 4. Fully gorged female rhipicephalus. *g. o.*=genital orifice; *a.*=anus; *r.*=rostrum.

Fig. 5. Alimentary canal of rhipicephalus. *a.s.*=alimentary sac; *c. l. t.*=common lateral trunk; *l*=anterior middle and posterior lateral diverticula; *p*=posterior diverticula; *a. l.*=small accessory lateral diverticula; *p. l. d.*=position of post. lat. diverticulum on ventral surface; *r.*=rectum; *s. gl.*=salivary gland; *c. g.*=cephalic gland.

Fig. 6. Epithelium of alimentary sac of rhipicephalus. *p. c.*=large projecting cell; *b. c.*=basal cell.

Fig. 7. Portion of salivary gland showing loose arrangement of acini (Rhipicephalus).

Fig. 8. Single acinus of salivary gland of rhipicephalus. Haematein.

Fig. 9. Ditto. Fresh preparation in hypotonic saline solution.

Fig. 10. Section through rostrum of rhipicephalus. *m*=cheliceris; *p. o.*=pumping-organ; *s. d.*=salivary duct; *d. g.*=dermal glands.

Fig. 11. Female reproductive organs of rhipicephalus. *o.*=ovary; *ov.*=oviduct; *sp.*=spermatheca.

Fig. 12. Spermatozoa of rhipicephalus.

Fig. 13. Spermatheca of rhipicephalus. *sp.*=spermatheca; *ov.*=oviduct; *t. gl.*=tibular gland; *sph.*—spermatophores; *t. sph.*—tube of spermatophore.

Fig. 1.

Fig. 2.

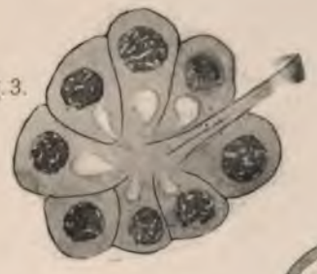
Fig. 3.

Fig. 4.

Fig. 5.


Fig. 6.


Fig. 7.


Fig. 8.


Fig. 9.

Fig. 10.


Fig. 11.

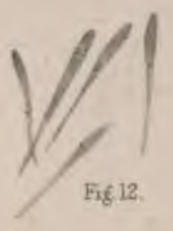
Fig. 12.

Fig. 13.

Photogravure.

Survey of India Offices Calcutta.June

(*NEW SERIES.*) No. 23.

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA.

THE ANATOMY AND HISTOLOGY OF TICKS.

BY

CAPTAIN S. R. CHRISTOPHERS, M.B., I.M.S.

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA, SIMLA.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
1906.

Price Rs. 3 or 4s. 6d.